The Environmental Impacts of the Mail: Initial Life Cycle Inventory Model and Analysis

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Life Cycle Inventory Analysis of the U.S. Mail

EXECUTIVE SUMMARY

The U.S. Postal Service, Environmental Policy and Programs, has commissioned this life cycle inventory (LCI) model and analysis to examine the energy consumption, waste generation, and pollutant emissions associated with mail in the United States. An initial version of the model is complete, and enables, for the first time, a comparative analysis of the environmental aspects (e.g., pollutant emissions, solid waste generation) of different mail products. The model also allows the quantification of portions of the overall "environmental footprint" of the entire Postal Service.

The model can inform Postal Service management of the magnitude and distribution of the major environmental aspects of postal operations, identify those portions of the mail life cycle that consume the most energy and generate the greatest amounts of pollution and waste, and quantify the share attributable to each major USPS product. Armed with this information, the Service, the mailing community, and the general public can evaluate and target efficiency and business improvement activities where they can have the greatest impact. More generally, they can use the model to develop a sense of the magnitude of the energy consumption and waste and emissions resulting from creating, handling, transporting, and delivering the entire U.S. mail stream, and begin to compare key indicators with those of other organizations, industries, and the national economy.

LCI analysis offers a consistent, internationally recognized means of comparing products, services, and functions from an environmental perspective, and is in increasing use by governments, corporations and trade associations, advocacy groups, and many other organizations. Life cycle *inventory* analysis is a component of life cycle analysis (LCA), which is a broader set of methods. Both examine "end-to-end" environmental aspects, that is, the waste and emissions from the creation of materials through manufacturing, distribution and sale, consumer use, and post-use management (e.g., disposal). LCI analysis characterizes waste and emissions rates and quantities, but does not examine the fate of released contaminants in the environment or ultimate human health or environmental impacts. LCA, including LCI, relies upon a set of standard terms and conventions that are defined in a series of consensus international standards issued by the International Organization for Standardization (ISO). Wherever practical, the current model and analysis have been developed in accordance with these standards.

To facilitate transparency and ease of use, we have constructed the model in spreadsheet format. This allows the user to examine in detail, the data and assumptions employed in conducting the Postal Service's initial LCI analysis, intermediate calculations and results, and particular life cycle stages. The model covers the entire life cycle of the mail, from the creation of the materials comprising the mail (e.g., paper and paper board, plastics) all the way through the ultimate disposition of the mail piece following use by the recipient. Environmental aspects and energy consumption associated with *transport* of the mail and its components across all life cycle stages also are included. This model can concurrently analyze as many as four distinct mail products, and yields results on both a unit and total basis.

In keeping with our stated objective and established LCI principles, we have focused on the most significant life cycle stages, both internal and external to the Service. Due to data limitations, the scope of the model is limited to a small number of indicator variables that include energy consumed, solid waste generated, one major water pollutant, and several air pollutants (five major pollutants plus carbon dioxide). Most of the data used in building the model originated within the Postal Service or relevant U.S. federal government agencies (e.g., Departments of Energy and Transportation, Environmental Protection Agency). Additional data were obtained from published papers and reports, industry studies, and from limited primary research. The model contains all of these data, as well as intermediate calculations, and so is self-standing and complete. In contrast to a number of other LCI studies, we did not create any fundamentally new consumption or emissions data in developing the current model; no new measurements or counts have been made. Instead, we have made use of several previously published, peer-reviewed studies that provided the needed factors and rates for life cycle energy consumed, waste generation, and pollutant emissions.

To populate and test the model, we have used the four major classes of mail: First-Class Mail, Standard Mail, Periodicals, and Package Services. We have treated each as a uniform category, using overall average values to define the relevant characteristics of each class, though subsequent versions could disaggregate the classes as desired. Wherever possible, we have collected and employ data representing FY 2006, so as to provide a consistent and recent time period for analysis.

In keeping with broadly accepted LCI modeling practice, we have employed a basic model structure focused around a common "functional unit" that allows "apples-to-apples" comparisons across different mail products. The functional unit used for all major model components is *one million pieces of mail*.
For each mail product, the model takes characteristics such as size, weight, density, and composition, and computes the quantities of materials (principally paper, cardboard, plastics, ink, and adhesives) consumed in producing it, and the waste and emissions associated with each of these materials, including the energy and emissions from transporting the materials. The model user may specify a number of mail product characteristics, as well as the transportation modes and distances involved in moving the product and its component materials between the various life cycle stages.

We have completed initial model runs and analysis, and results reveal several interesting findings:

- Solid waste generated across the life cycle by the four major mail products amounts to 9.7 million tons, and the amount discarded post-use amounts to 5.4 million metric tons, which is about 13 percent of the amount of paper and paper board that is discarded in the municipal solid waste stream annually in the U.S.
- The share of each pollutant that is attributable to Postal Service operations is highly variable, but is uniformly within the top five (of 17) life cycle stages, along with the paper and board manufacturing, printing/mail production, dropshipping, and, for both solid waste generation and carbon dioxide emissions, landfill disposal life cycle stages.
- On a unit basis, Periodicals and Package Services have the highest pollutant emissions and energy consumption, because of their relatively high weight and (for Periodicals) high paper and printing content. On an overall basis, however, Standard Mail accounts for the largest share of energy consumption and pollutant emissions among the four major mail Classes, because of its much higher volume relative to other classes.

Several limited but relevant comparisons of the initial model results with other published studies suggest that these results are reasonable and realistic, i.e., emissions, waste, and energy use estimates are within a range that seems credible.

- The estimated quantities of solid waste generated by the Standard Mail and Periodicals classes as predicted by the model are within 25 percent of published EPA figures for 2006.
- Total energy consumed by the four mail products accounts for 0.6% of national energy consumption, a figure that seems reasonable given the quantities of mail in the U.S. economy, and the energy-intensive nature of paper and board production, printing, and motor vehicle transportation.
- At the household level, energy and CO2 emissions associated with the entire mail life cycle are roughly comparable to those from operating any of several common home appliances over the same period of time.

Following completion of the initial LCI model and application, the Postal Service conducted a formal peer review process on these products. The process involved three well-known external experts, and yielded a number of suggested improvements, in addition to the consensus finding that the model is appropriately developed and fully and clearly documented. We have made several substantial refinements to the initial model based upon preliminary peer review comments, and are considering additional improvements suggested by reviewers as part of the next phase of model development.

We believe that this initial version of the LCI model represents a significant advancement in the Postal Service's ability to understand and quantify the environmental aspects of the mail. Next steps include further development of the model's structure, components, and supporting data.

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The Environmental Impacts of the U.S. Mail: Initial Life Cycle Inventory Model and Analysis

I. Introduction

This report describes the analytical framework and methods used in this first analysis of the life cycle inventory of the major categories (Classes) of the U.S. mail. The Postal Service has performed this analysis as a starting point for its efforts to improve its environmental footprint and also in response to the growing attention being paid to certain types of mail, based upon claims that this mail imposes a number of undesirable impacts on the environment. Thus, we have developed an analytical framework for evaluating the direct and indirect environmental aspects of mail service, and the broader life cycle aspects of the mail and its components. The scope and level of precision of our analysis are tailored to address the issues raised by and within the mailing industry, public interest organizations, and the general public. That is, the analysis and underlying methods are intended to inform discussions at the organizational policy level, rather than at the more detailed level of capital budgeting, pollution control engineering, program management, and similar activities.

Because of the size, ubiquity, and complexity of the mail stream, we have not attempted here to evaluate the potential or actual hazards posed by the mail and its subsidiary activities to human health and the environment. Such an undertaking would be extremely complicated, time-consuming, and expensive. Instead, we have focused on taking an initial but important step in understanding the ultimate human health and environmental impacts of the mail by characterizing the waste, pollutant emissions, and energy consumption involved in its delivery by conducting a comprehensive life cycle inventory (LCI) analysis of the four major U.S. mail products. We also have conducted some limited comparisons of our initial results with a variety of data, indicators, and analytical results addressing mail and closely related products.

The remainder of this report describes our methods, preliminary results and their apparent realism, and areas of uncertainty and for further development. Section II describes the framework that we have developed to conduct the LCI analysis, the general approaches that we have employed, and a number of major assumptions that underlie our preliminary estimates. Section III presents the basic structure and functions of the LCI model. This section also addresses the major sources and types of data that we have assembled to quantify the creation and flow of the mail, and the environmental aspects that arise from each stage in its life cycle. Section IV presents a summary of our preliminary results, and provides some comparisons to other data and analytical results. These comparisons help to put our results into context and also provide a basis for assessing the realism of our model and its outputs. Section V provides a discussion of important areas of uncertainty and possible further model and data development. Finally, Section VI describes the formal peer review process employed by the Postal Service to review the LCI model and this report, and discusses the major outcomes resulting from this review. A description of the LCI model and final peer reviewer comments are attached as Appendices A and B, respectively, to this report.

II. Framework, General Methods, and Major Assumptions

The Postal Service has asked us to perform several related analyses that speak to the environmental impact of the U.S. mail. While the outputs of these analyses differ somewhat, they all focus on end-to-end delivery of all mail types across and throughout the U.S. and internationally. Accordingly, a common frame of reference is essential. The overarching concept used here is life cycle analysis (LCA), which examines the environmental impact of a product or service from its initial extraction of raw material resources through its final disposition. LCA provides the most complete perspective from which to evaluate environmental impact, and also facilitates comparisons between the mail and other possible substitutes.

Today, most practitioners of LCA use a set of standard terms and conventions that have been defined in a series of consensus international standards.[1] These standards define and distinguish between two basic types of life cycle studies: Life cycle inventories (LCI) and life cycle analysis (LCA). The important distinction between the two is that the latter includes an additional phase, impact assessment, that represents an attempt to link the pollutant emissions and other environmental aspects quantified by the LCI to categories and indicators of actual (or potential) human health or environmental impact. This study and model comprise an LCI, and hence include the three phases of goal and scope definition, inventory analysis, and interpretation. Application of the LCI approach requires several important decisions regarding, in particular, the goal(s), scope, boundaries, and focus of the study, which for this analysis are presented in Exhibit 1.

Exhibit 1
Major Study Parameters

Term	Description	Reference
Goals	To carefully, fully, and objectively examine the environmental aspects of the U.S. mail, so as to enable sound decision making by USPS management and begin to respond to concerns expressed by various stakeholders. Model results may be made public either generally or on a limited, as-requested basis.	ISO 14044, Section 4.2.2
Scope-general	The entire U.S. mail stream processed by the U.S. Postal Service, including the components thereof delivered to all domestic locations, and mail transported by third parties for portions of its life cycle. All phases of the preparation, handling, delivery, and ultimate disposition of mail and its major components, as well as the raw material and other resources required to manufacture them. Postal Service employee commuting, manufacturing of durable (capital) equipment, and other secondary and tertiary dimensions of the mail life cycle are not included.	ISO 14044, Section 4.2.3.1
Assumptions and Limitations	1. Major mail products (Classes) can be adequately characterized using overall average values for major characteristics (e.g., weight, material composition) 2. Use of a limited number of constituents and other environmental aspects is sufficient to generate first-order estimates of a life cycle inventory for the mail stream 3. Lack of full inventory data for some life cycle stages (e.g., water pollutant emissions generated by vehicle operations) does not undermine model results showing the relative importance of various life cycle stages or the overall validity of the study	ISO 14044, Section 4.2.3.1
Functions	1. Secure transmission of information and images, often in large and/or complex form, from one specific party to another. 2. Secure transport of goods from one specific party to another.	ISO 14044, Section 4.2.3.2
Functional Unit	1. Transmittal of one million discrete sets of information and/or images, from sender to recipient located at any address in the U.S. 2. Transmittal of one million discrete goods or sets of goods from sender to recipient located at any address in the U.S.	ISO 14044, Section 4.2.3.2
System Boundary	Complete end-to-end preparation, delivery, and disposition of the mail and its component parts, both content and packaging.	ISO 14044, Section 4.2.3.3
Allocation Procedures	Allocation among postal products will be minimized by relying upon Class and subclass level data where available. Where allocation is required, it will be applied to the functional unit on the basis of USPS procedures for allocating resource usage to mail class; these procedures are based on causal relationships between relevant environmental aspects (e.g., fuel consumption) and the activities that cause, create, or strongly influence these aspects. Data for implementing these procedures are publicly available and have been approved by the Postal Regulatory Commission.	ISO 14044, Section 4.3.1
Data Quality Requirements	Maximum possible use of published data from USPS, U.S. EPA, and other government agencies preferred, along with peer-reviewed literature (e.g., for raw	ISO 14044, Section 4.2.3.6

[1] Specifically, the ISO 14040 series of standards, guidelines, and technical references on Life Cycle Assessment.

	material life cycle inventory values), and EPA or other Agency-sponsored models and data sets. All data to be sourced and supporting data to be documented. Data reflective of U.S. operations and activities only. Development of entirely new data limited to consultation with industry experts to address specific data gaps.	
Critical Review Considerations	Written report for the USPS internal environmental management function, with possible subsequent release to external parties, including the general public. Critical peer review of methods and data following completion of the initial model prototype.	ISO 14044, Section 4.2.3.8

Most of the points of divergence from the ISO Standard concern ways in which we have adapted the LCI approach articulated in ISO 14044 to make our model and its outputs more immediately relevant to the business decisions faced by the Postal Service. For example, our LCI model does not track "elementary flows" as specified in the Standard (Section 4.2.3.3.3), but instead tracks (primarily) the flows of the major materials comprising the mail (paper, paper board, and plastic) as well as fuels. The material flows that we have chosen are more easily understood, measured, and accounted for across the Service than elementary flows, and in some cases are under the control or influence of USPS managers. Also, given the relatively early stage of the development of our LCI model, we have not stated our data quality requirements and treatment of missing data at the level of detail outlined in the Standard (at Section 4.2.3.6). Finally, as described below, we have developed some limited comparisons of our results with those of other studies of mail or mail components so as to evaluate the realism and reasonableness of our results. This step is contrary to ISO 14044, Section 4.2.3.7, which stipulates that comparative studies to be released to the public must include a life cycle impact assessment (LCIA). We believe that conducting an LCIA of the mail using our LCI results would be a very complex and difficult undertaking, and that at this time, the Postal Service is better served by completing and refining the current modeling framework and its initial application.

Constituents and Endpoints of Concern

We have applied some simple screening criteria to determine which constituents and other endpoints to include in the LCI model. These criteria have assisted us in keeping the analysis at a tractable size, while ensuring that we have considered all potentially important materials, activities, and endpoints.

Mass contribution. Except in the case of particularly toxic or otherwise problematic constituents, we generally exclude from analysis constituents of a material (whether product or non-product) that comprise less than one (1.0) percent of the total mass of the material in question. This assumption is consistent with those employed in other recent life cycle studies addressing products entering the mail stream; as described below, some of these studies are used as significant data sources for the current analysis.

Energy contribution. In similar fashion, we have focused on the processes associated with a particular activity or life cycle stage that, in combination, equals at least 99 percent of the total energy accounted for or consumed by that activity or stage.

Environmental or human health relevance. For environmental aspects, we have evaluated all available data sources for information on constituents that are known to be of concern from a human health and/or environmental protection standpoint. In practice, we have accomplished this by determining which of the candidate constituents have established U.S. EPA reference doses, cancer slope factors, primary drinking water standards, air quality criteria (e.g., NAAQS, NESHAP), or ambient water quality criteria. Generally, constituents that are present in low concentration or sporadically have been eliminated from further analysis unless they possess carcinogenic potential or are acutely toxic to humans or biota. We have used simple material composition and mass balance calculations to implement this screening approach.

The results of applying these criteria are described below in Section III.

Major Unit Processes

In building an LCI model addressing the mail stream, we have analyzed the energy consumed by and waste and emissions resulting from the mail at two major levels: preparation, transport, handling, and delivery of the mail itself; and the major materials comprising the mail. The major participants, steps, and environmental aspects of the former are outlined at a general level in Exhibit 2, below. For each mail product included in the analysis, we consider the energy consumed and waste and emissions generated in producing the raw materials used (not shown), then fabricating the mail piece through a variety of cutting, printing, folding, packaging, addressing, sorting, and other steps. At that point, the mail piece is entered into the Postal Service system, either locally or following dropshipping by the mailer or (more commonly) a consolidator. The Postal Service receives and processes the mail and transports it (directly or by using a vendor) to another processing plant and on to the delivery unit or directly to the delivery unit, which then delivers the mail to the intended recipient. The mail recipient either discards the mail at some point following receipt, or keeps a percentage on a long-term basis. Mail that is not retained may either be recycled or discarded, at which point it enters the municipal solid waste (MSW) stream. The model apportions the weight percentage of the mail that reports to recycling, landfill disposal, and processing at a waste-to-energy facility according to user-defined assumptions.

The model also addresses the transportation required to move the mail and its components between each life cycle stage, starting with delivery of the paper and other materials comprising the mail to the mail originator, ending with the final disposition of the discarded fraction of the mail in a landfill or other end-of-life management option, and covering all the stages in between. Due to a paucity of data on pollutant emissions to water and land and the fact that most transport-related pollutant emissions are fossil fuel combustion emissions to air, the LCI of the transportation steps in the life cycle is limited to tracking of several major air pollutants as well as the energy (fuel) consumption involved in moving the mail from one life cycle stage to the next.

Exhibit 2
General Life Cycle of the Mail

Entity	Mailer or Vendor		U.S. Postal Service		Mail Recipient		MSW Manager	
Life Cycle Phase	**Materials Processing**	**Mail Preparation**	**Receipt and Processing**	**Delivery Unit Receipt and Processing**	**Recipient Receipt and Use**	**Recipient Disposition**	**Material Acquisition & Handling**	**Material Disposition**

Major Steps	• Cutting
	• Printing
	• Adhesive application
	• Folding, sorting, packing, and sealing
	• Storage
		• Printing/writing
		• Wrapping
		• Packing, sealing, addressing, and postage application
			• Acceptance
			• Scanning/ barcoding
			• Sorting
			• Bundling
			• Loading for Transport
				• Receipt
				• Sorting
				• Storage/ queuing
				• Loading
					• Opening
					• Review and Use
						• Discard
						  • Packaging
						  • Contents
						• Disposal
						• Recycling
						  • Curbside
						  • Drop-off
						• Reuse
							• Collection
							  • Single-Stream
							  • Sorted
							• Sortation & preparation for transport
								• Landfill disposal
								• Energy recovery

Environmental Aspects	• Electricity use
	• Solvent emissions
	  • Printing
	  • Press cleaning
	• Solid waste
	  • Cuttings & other wastage
		• Electricity use
		• Solvent emissions
		  • Printing
		  • Press cleaning
		• Solid waste
		  • Cuttings & other wastage
			• Electricity use
			• Solid waste
			  • Undeliverable mail
			  • Worn out shipping containers & boxes
				• Electricity use
				• Solid waste
				  • Worn out shipping containers & boxes
				  • Straps, sleeves, polywrap
					• None	• Solid waste
						  • Paper & plastic envelopes
						  • Cardboard boxes & tubes
						  • Sheet paper
						  • Catalogs & magazines
						  • Packing material
							• Electricity use
							• Heavy equipment fuel use
							• Heavy equipment air emissions
							• Solid waste
							• Unrecoverable material
								• Electricity use
								• Heavy equipment fuel use
								• Heavy equipment air emissions
								• WtE combustion gas emissions
								• WtE combustion ash and scrubber residue
								• Landfill methane emissions
								• Landfill leachate treatment effluent and sludge

Transport Method (to next phase)	• Medium-Large Truck • Automobile	• Medium-Large Truck • Automobile	• Large Truck • Train • Airplane • Boat	• Medium Truck • LLV		• Large truck • Automobile (consumer drop-off recycling only)	• Large truck	• Large truck
Environmental Aspects	• Fuel consumption • Vehicle air emissions	• Fuel consumption • Vehicle air emissions	• Fuel consumption • Vehicle air emissions	• Fuel consumption • Vehicle air emissions		• Fuel consumption • Vehicle air emissions	• Fuel consumption • Vehicle air emissions	• Fuel consumption • Vehicle air emissions

III. LCI MODEL STRUCTURE, FUNCTIONS, AND DATA

The LCI model addresses all major life cycle stages for a list of indicator constituents and endpoints, and both enables comparisons among mail products and provides unit and total estimates of pollutant emissions, waste generation, and fuel and energy use for each product. We describe here the initial configuration of the model, which examines the life cycle aspects of the four major U.S. mail Classes: First Class; Standard; Periodicals; and Package Services. With minor modifications, this model could be adapted to examine other Postal products as well.

Brief Description of Model Structure

We have chosen to house the LCI model and its underlying data in MicroSoft Excel®, a widely used and available spreadsheet program. Using a spreadsheet format for the model provides transparency regarding model components and data, enables ongoing incremental improvements to the model, and facilitates the study of individual components of the mail's life cycle, according to the interests of the user. At present, the model consists of 37 linked worksheets, which contain all model calculations and data. Collectively, these worksheets contain the background information, assumptions, and intermediate calculations used to calculate model results:

- Six worksheets at the front of the workbook contain detailed LCI results; the tab color for these is white. Two contain results at the functional unit level (one million pieces of mail), two contain results on a per mail mass (kg) basis, and two contain total results. Within each category, results for energy consumption and waste generation and pollutant emissions are provided on separate worksheets.

- One worksheet contains some tabular results illustrating certain issues of particular interest, including carbon dioxide emissions and waste management practices. This worksheet is colored red.

- Next, three worksheets having a black tab color contain, respectively, basic data required to run the model, assumptions, and standard values; and information on the specific mail products being analyzed. Most of the values in these three worksheets are drawn from more basic, detailed data that are provided at the end of the workbook.

- Calculations that characterize the activities, energy consumption, and waste generation and pollutant emissions occurring at each major mail life cycle stage are presented in a series of 14 worksheets that have tabs colored medium blue. These are presented in the general order of each stage in the life cycle of a typical mail piece.

- Finally, supporting data and, in some cases, supplementary calculations are provided in a series of 13 worksheets with tabs that are colored orange.

Details on each of these LCI model worksheets are provided in Appendix A to this report.

Waste and pollutants are expressed as kg/million pieces of mail, except on the final summary sheets, where they are expressed on the basis of either metric tons (MT) or in grams per kilogram of mail product. Fuels data are generally expressed in the units that are typically used for each one (e.g., kWh for electricity, thousand cubic feet for natural gas, gallons for liquid fuels), though they all are normalized in the summary worksheets to common units (million British Thermal Units (BTUs)). Within each subsidiary worksheet, consumption of each fuel is normalized and expressed on the basis of the functional unit (e.g., gallons of diesel fuel per million mail pieces).

Wherever possible, the full life cycle implications of using materials and fuels are considered and summed to provide a complete picture of the scale of the environmental aspects of mail products. So, for example, in computing the aspects from using a gallon of diesel fuel, the model includes not only the direct combustion emissions, which are dependent upon the type of engine or device burning the fuel, but also the waste and pollution generated and energy used to *produce* the fuel. In some cases, these upstream aspects can be of significant magnitude.

To provide flexibility and utility for examining different issues and scenarios, the model contains a number of user-defined inputs. These have been pre-populated with data values, which may be modified as desired; these are shaded in aqua. Most of these inputs pertain to the composition, handling, and post-use management of the mail, which can all be adjusted to reflect the characteristics of individual mail products. In addition, the specified transport modes and distances used in the model (which apply to all products) may be adjusted as desired.

Model Functions

As currently configured and populated, the model can independently evaluate the LCI of up to four distinct mail categories, or "products." For our initial analysis, we have treated each of the four mail Classes as a uniform category, using overall average values to define the relevant characteristics of each Class. Nevertheless, as explained below, the model is capable of evaluating individual subclasses, shapes, and other mail sub-categories when and as desired. Wherever possible, we have collected and employ data representing U.S. government fiscal year (FY) 2006, so as to provide a consistent and recent time period for analysis.

As stated above and in keeping with broadly accepted LCI modeling practice, we have employed a basic model structure focused around a common functional unit that allows "apples-to-apples" comparisons across different mail products. The functional unit used for all major model components is *one million pieces of mail*.

For each mail product, the model takes characteristics such as size, weight, density, and composition, and computes the quantities of materials (principally paper, cardboard, plastics, ink, and adhesives) consumed in producing it, and the waste and emissions associated with each of these materials, including the energy and emissions from transporting the materials. We have conducted our initial analysis using the conservative assumption that the mail pieces are not retained by the user and all mail delivered[2] is modeled as being discarded within one year of receipt, yielding a steady state condition. The model does, however, have the capability to accept a different assumption, and can assess the impact of assuming that variable percentages of each mail product are retained by the recipient.

Following use, post-consumer management of the mail piece and its components is addressed by segregating the portion of the functional unit managed using each major management method (recovery, landfill disposal, and combustion) according to user-specified values and assumptions, and tracking these fractions through their ultimate disposition. Again, waste and emissions for each life cycle stage and transport among them are computed and tallied by the model.

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[2] An exception this general rule exists for Package Services. The user-specified weight percentage of the packages that consists of their contents is retained, and all packaging is discarded. We have assumed for our initial analysis that 85 percent of the weight of packages entering Package Services consists of content and the remaining 15 percent consists of packaging.

Allocation of Common Mail Processing Inputs and Outputs

As discussed below, initial application of our LCI model indicates that Postal Service operations contribute a significant fraction toward the overall "environmental footprint" of the mail. This finding, while unsurprising, does imply that achieving accuracy and clarity regarding the contribution of each mail product's share to the overall resource consumption and pollutant emissions of Postal operations is a matter of some importance. The Postal Service consumes substantial quantities of energy in operating its facilities, processing mail, and transporting mail between its facilities and the mail recipient. Newly available data on the aggregate quantities of energy consumed by the Postal Service in FY 2006 have been provided to us by the Service. Using these data, it is possible to make some inferences about the total quantities of fuel that have been used in particular transport and delivery operations. But these data do not reflect the quantities of fuels used that are attributable to individual mail products. Indeed, because most Postal transport and all delivery operations handle multiple products simultaneously at the level of the individual vehicle, developing a "bottom up" inventory of fuel use by product is not possible. Instead, a means of allocating these fuels to the individual products is necessary. It is important to note, however, that the allocation does not affect the total resource consumption and pollutant emissions of the Postal Service, but only the distribution of these environmental aspects among different mail products.

To accomplish this distribution by product, we have used a relatively simple but rigorous "top down" approach in which we allocate shares of resource usage and pollutant emissions to mail products based upon each product's share of the resource usage that creates these missions. These shares for each mail product and service are tabulated and published by the Postal Service annually, and are organized by cost segment and component. The model also provides the capability to allocate the shares to mail products using three alternative methods: the weight, mail volume (number of pieces), or physical volume ("cube") of the product. None of these alternative measures are based upon causal or even direct relationships with the resource usage under study and thus do not comport with ISO 14044, Section 4.3.4.[3] Further, in some instances they provide results that not only differ from our causal allocations, but also from each other and there is no basis in logic or causality for choosing among these three methods. Nonetheless, we provided this capability in response to comments from a peer reviewer and to respond more fully to the expectations stated in ISO 14044, Section 4.3.4.1. We also present the results of a sensitivity analysis of our results using these alternative distribution keys in Section IV, below.

In the base case LCI model, we have applied the resource usage shares to the data on transportation and facility operation fuels. This allows us to determine the full energy consumption and pollutant emissions generated during Postal Service handling, transportation, and delivery of each mail product. The remaining portions of the fuel use and associated emissions that are not allocated to one of the four mail products considered by the model are distributed to all other mail products, USPS services ("Special Services"), and finally, to Postal Service institutional, or "network," operations. Exhibit 3 illustrates how this allocation process is applied.

The Postal Service is fundamentally a service business, not a manufacturing or utility enterprise. While there are doubtless other environmental aspects associated with the Postal Service's stages in the mail life cycle beyond fuel consumption and related pollutant emissions, we do not believe that they are likely to be significant given the life cycle inventory parameters stated above. The one possible exception concerns solid waste generation, which is treated separately in the model and discussed further below.

[3] ISO 14044, Section 4.3.4.2 (Allocation procedure) states, in part, "Where allocation cannot be avoided, the inputs and outputs of the system should be partitioned between its different products or functions in a way that reflects the underlying physical relationships between them."

Exhibit 3
Allocation of Postal Service Inputs and Environmental Aspects

USPS Cost Segment/ Component	Name	Variable Applied to	Intermediate Result	Final Result
15.2/314	Fuel & Utilities	Total facility energy consumption by fuel	Mail product share of USPS electricity, natural gas, and heating oil consumed	Energy consumed, life cycle pollutants emitted by fuel for each mail product and for the entire USPS
14.1/142, 681	Domestic Air, Domestic Air Alaska	Total aviation fuel consumption (weighted average used)	Mail product share of aviation fuel consumed by USPS contract carriers	Energy (gallons, BTUs) consumed, life cycle jet fuel pollutants emitted for each mail product and for the entire USPS
14.1/143	Highway	Total HCR, bulk, and mobile fuel consumed	Mail product share of trucking fuel (diesel, gasoline) consumed by USPS haul trucks and highway contract carriers	Energy (gallons, BTUs) consumed, life cycle highway transport fuel pollutants emitted for each mail product and for the entire USPS
14.1.3/144	Railroad	Total Railroad fuel consumed	Mail product share of rail fuel (diesel) consumed by USPS rail carriers	Energy (gallons, BTUs) consumed, life cycle rail transport fuel pollutants emitted for each mail product and for the entire USPS
7.2/46	Delivery Activities (City)	Postal Fleet-Voyager-Retail fuel consumed	Mail product share of delivery fuel (diesel, gasoline) consumed by USPS city carriers	Energy (gallons, BTUs) consumed, life cycle city delivery fuel pollutants emitted for each mail product and for the entire USPS
10/260	Rural Carriers	Rural Routes fuel consumed	Mail product share of delivery fuel (gasoline) consumed by USPS rural carriers	Energy (gallons, BTUs) consumed, life cycle rural delivery fuel pollutants emitted for each mail product and for the entire USPS

Solid waste is generated at numerous (nearly all) stages of the mail's life cycle. Because, however, all such waste is treated by one of a small number of management methods, we have aggregated the solid waste generated at each stage into a set of inputs shown on the worksheets comprising the final stages in the mail life cycle (Collection & Material Recovery, Residual Disposal-WtE, and Residual Disposal-Landfill). In addition, because of the full life cycle perspective of the model and prevailing patterns of MSW management in the U.S., ultimately, the majority of the solid waste generated at various life cycle stages ends up being disposed in a landfill. In the LCI model, we use a simplified approach in which all of the solid waste quantities reporting to landfill disposal are aggregated on a single worksheet (Residual Disposal-Landfill), though in reality, solid waste generated through the life cycle is disposed locally at each stage. The quantities of solid waste generated at each of the upstream stages can be observed on the worksheet for that stage, as desired.

Data

This section of the report first discusses the major data sources used for populating the model. It then goes on to discuss the variability our use of the data has introduced and the uncertainty in our data.

Major Data Sources

As suggested above, the LCI model uses a variety of different types and sources of data. Some of the more important elements are briefly profiled here.

The major materials comprising the mail include various types and grades of paper and paper board, plastics, adhesives, and packing materials. This implies that developing an understanding of the resources required to manufacture these materials and the associated wastes generated and pollutants emitted is important to being able to complete a life cycle inventory for the mail in any meaningful way.

Fortunately, detailed life cycle inventories of many of these materials have recently been developed, and we have drawn heavily upon this work in assembling and analyzing the end-to-end life cycle aspects of the mail. Pertinent data for the materials and unit processes for which we have inventory data are presented in Exhibit 4. These include both the environmental aspects of manufacturing various types of paper, paper board, and plastics, and also the pre-combustion (upstream) waste, energy consumption, and pollutant emissions associated with producing various types of transportation fuels. In some cases (e.g., life cycle pollutant emissions from electricity consumption), these data have been supplemented with more recent data drawn from other sources. In other cases (emissions from transportation equipment), we have replaced some of the data with information from more recent sources.

Exhibit 4
Major Materials Comprising the Mail:
Available Life Cycle Inventory Data [a/]

Major Category	Specific Material or Process	Life Cycle Stage(s) Considered	Endpoints Considered
Materials	• Bleached Virgin Kraft Paper • Unbleached Virgin Kraft Paper • Unbleached Recycled (100%) Kraft Paper • Virgin Newsprint • Recycled (100%) Newsprint • Virgin LDPE Film • Recycled LDPE Film • Virgin LDPE Air Packets • Recycled LDPE Air Packets • Virgin EPS Loose Fill • Recycled EPS Loose Fill • Cornstarch Loose Fill • Molded Pulp Loose Fill (100% Recycled) • Corrugated Cardboard Boxes (38% Recycled) • Corrugated Cardboard Boxes (80% Recycled)	Manufacture	• Raw Material Consumption • Process Energy (by type) • Transportation Energy (by type) • Solid Waste • Air Emissions • Water Emissions
Fuels	• Coal • Natural Gas • Residual Fuel Oil • Distillate Fuel Oil • Gasoline • Diesel Fuel • Liquified Petroleum Gas • Uranium	Production	• Energy Use • Solid Waste • Air Emissions • Water Emissions
		Transportation	• Energy
		Use (by major type)	• Total Energy Consumed • Solid Waste • Air Emissions • Water Emissions
	• Electricity	Generation	• Fuel Mix

[a/] Source: Franklin Associates, 2004. *Life Cycle Inventory of Packaging Options for Shipment of Retail Mail-Order Soft Goods.*

Beyond this relatively rich source of relevant LCI data, information on other components of the mail life cycle is sparse. To address this limitation, we have collected and adapted a series of fuel consumption and pollutant emission factors from published sources to quantify some of the important environmental aspects of life cycle stages downstream of raw material manufacturing. As a result, and to keep the model and analysis at a manageable scale, we have included only selected major air and water pollutants in the LCI model. Thus, while LCI data for the major paper, board, and plastics components of the mail stream are extensive and are included within the model for illustrative purposes and for possible further developmental work, only a more limited suite of aspects is computed, aggregated, and reported across all of the life cycle stages of the mail. These aspects are listed in Exhibit 5.

Exhibit 5
Endpoints Included in the LCI Model

Environmental Aspects	Energy Consumption
Solid waste	Transportation fuels consumed - Gasoline - Diesel - Jet fuel
Water pollutants - Total dissolved solids	
Air pollutants - Carbon Dioxide - Carbon monoxide - Hydrocarbons - Nitrogen oxides (NOx) - Particulate matter - Sulfur oxides (SOx)	Manufacturing, preparation, and facility energy consumed - Electricity - Natural gas - Liquid fuels

Interestingly, hazardous waste is not among these endpoints. As counter-intuitive as this may seem, review of our major data sources showed that negligible or very small quantities of hazardous waste are expected to be generated by the activities comprising the mail life cycle and addressed by the LCI model.

Other major data types and sources employed in building the LCI model are presented in Exhibit 6. As stated above, wherever possible, we have used published data from authoritative U.S. government sources or peer-reviewed studies. As shown in this table, we have made extensive use of approaches and data developed by the U.S. Environmental Protection Agency (EPA). EPA has developed standardized approaches, specific methods and models, and extensive empirical data for various endpoints of interest (e.g., air pollutant emission rates for different engine types and sizes). Moreover, EPA's methods and most of its data have been extensively peer reviewed and revised and refined repeatedly during the past 20 years or so. We believe that these methods and data, when appropriately employed, are the best available.

Exhibit 6
Major Data Sources for the Mail Product LCI Model

Data Element(s)	Source	Principle Use
Transport fuel economy and cargo capacity for trains and trucks	Bureau of Transportation Statistics, U.S. Department of Transportation (DOT). 2007. *National Transportation Statistics*. Tables 4-13, 14, and17.	Unit fuel consumption for mail and other materials
Fuel conversion factors	Energy Information Administration, U.S. Department of Energy. 2007. Found at http://www.eia.doe.gov/basics/conversion_basics.html	Converting fuel gallons to units of energy
Equipment sizes and configurations needed for landfill operation	*Tchobanoglous, G. 1993. Integrated Solid Waste Management: Engineering Principles and Management Issues.*	Calculation of unit air pollutant emissions from heavy equipment required for post-use mail management

Densities and other physical constants of materials	*Pocket Ref*. Undated. Sequoia Publishing, Inc., Pp. 427-436.	Calculation of volumes of materials for shipment, management, and other activities
Average pollutant emissions from U.S. electricity production-2006	U.S. Environmental Protection Agency (USEPA), 2007. eGRID2006 Version 2.1. Found at http://www.epa.gov/cleanenergy/egrid/index.htm	Calculation of pollutant emissions from facility equipment and building electricity use
Contained energy and greenhouse gas potential of materials in MSW	USEPA, 2006. *Solid Waste Management and Greenhouse Gases: A Lifecycle Assessment of Emissions and Sinks*. Pg. 71.	Calculation of net energy consumption and greenhouse gas emissions from post-use mail management
Passenger car fuel economy	USEPA, 2005. *Light-Duty Automotive Technology and Fuel Economy Trends: 1975 Through 2005-Executive Summary*. EPA420-S-05-0001. July.	Unit fuel consumption for passenger vehicles
Passenger car fuel economy and air pollutant emissions	USEPA, 2005. *Emission Facts: Average Annual Emissions and Fuel Consumption for Gasoline-Fueled Passenger Cars and Light Trucks*. Office of Air and Radiation, Office of Transportation and Air Quality, EPA420-F-05-022. August.	Calculation of unit air pollutant emissions from passenger vehicles
Heavy and medium duty truck fuel economy and air pollutant emissions	USEPA, 2005. *Emission Facts: Average In-Use Emissions from Heavy-Duty Trucks*. Office of Air and Radiation, Office of Transportation and Air Quality, EPA420-F-05-0yy. May. Table 1.	Calculation of unit air pollutant emissions from medium and heavy duty trucks
Air pollutant emission factors from non-road diesel engines	USEPA, 2004. *Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling--Compression Ignition*. OAR, EPA420-P-04-009. April.	Calculation of unit air pollutant emissions from heavy equipment required for post-use mail management
Energy and material consumption and air pollutant emission rates	USEPA, 2002. *Flexographic Ink Options: A Cleaner Technologies Substitutes Assessment.* Design for Environment Program; Doc. No. EPA 744-R-02-001A, February.	Calculation of unit air pollutant emissions and energy consumed from printing and preparing mail pieces
Cargo plane fuel economy and air pollutant emissions	USEPA, 1999. *Evaluation of Air Pollutant Emissions from Subsonic Commercial Jet Aircraft.* Office of Air and Radiation. Doc. No. EPA420-R-99-013. April.	Calculation of unit air pollutant emissions and fuel consumption from air transport
Train fuel economy and air pollutant emissions	EPA, 1997. Technical Highlights: *Emission Factors for Locomotives*. Office of Mobile Sources, EPA420-F-97-051, December.	Calculation of unit air pollutant emissions from rail transport
Volumes, weights, and physical characteristics of mail Classes	U.S. Postal Service (USPS), 2007. Cost and Revenue Analysis (CRA) Report-FY 2006. Worksheets "Volume 1," "Volume 2."	Calculation of required transportation equipment and related emissions, summaries of total environmental aspects from functional unit
Variable and fixed cost components of unit Postal operations	USPS, 2007. Cost Segments and Components.	Allocation of fuels to specific mail products
Postal Service truck and cargo van capacities	USPS, 2000. *United States Postal Service Specification: Semitrailers, Bulk Mail/Container Van*. USPS-Engineering: USPS-S-606QA. May 23.	Calculation of required numbers of vehicles to transport given quantities of mail
Postal Service cargo van capacities	USPS, Undated. *United States Postal Service Specification: Trucks, Diesel Engine Powered, Cargo Van: 6,532 Kilograms (14,400 pounds) 17 Foot Nominal Cargo Body, 9,981 Kilograms (22,000 pounds) 24 Foot Nominal Cargo Body.* U.S. Postal Service Engineering: USPS-T-118	Calculation of required numbers of vehicles to transport given quantities of mail
Postal Service delivery vehicle (LLV) capacities	USPS, 1987. *Fleet Management Bulletin. Subject: Procurement, Specification, and Warranty Data for the 1987 Grumman 1/2 Ton Long Life Vehicle (LLV)*. September 15.	Calculation of required numbers of vehicles to deliver given quantities of mail

Variability and Uncertainty

The data driving the model are subject to both variability and uncertainty. We discuss each in turn.

As presently configured, the model calculates the life cycle emissions of an average functional unit of each of the four major classes of mail: First-Class, Standard, Periodicals, and Package Services. But many of the variables that drive those emissions can take on a wide range of values, which the model generally summarizes using the average. Thus, the model uses the average weight of a piece of each of the classes of mail, when, for example, the weight of a piece of Standard Mail can range up to a pound and the weight of a piece of Package Services Mail can range up to 70 pounds. In similar fashion, some mail in each class is transported more frequently and over longer distances by the Postal Service than other mail within the same class, goes through more facilities, and is sorted more times, all requiring more energy and producing more emissions. Again, the model finds the emissions of the average piece (or functional unit) of mail. Consequently, because results are calculated for the average functional unit, they are far less valid for mail that assumes characteristics far removed from the averages. The model could, however, be configured to find the life cycle inventory for mail that varies from the average. Further, the model could be structured to disaggregate the mail within each class to reflect the wide range of variation within a mail class. Thus, for example, within Standard Mail we could structure the model to produce separate estimates for letters and for catalogs (which tend to be heavier than letters).

In spite of the fact that we have produced a single point estimate for the emissions associated with each of the four major classes of mail and that we have carried out the calculations to a large number of significant places,[4] we readily acknowledge that there is uncertainty in our results. The model worksheet "Assumptions & Standard Values" provides the basis for many of the assumptions in the model, and "best professional judgment" is not an uncommon entry in this worksheet. At a more general level, such uncertainties are very common in developing policy-relevant models, and generally are addressed in the same manner as in our analysis, by clearly stating what they are and how the values selected influence the overall results. In the case of our LCI model, most of the uncertainties are related to factors and behaviors of participants in the mail life cycle that are outside the Postal Service. We have addressed these uncertainties by applying a series of conservative but realistic assumptions made on the basis of our extensive knowledge of the mail stream and mail production and handling processes, solid waste management practices, and related activities. In many cases, specific assumptions are based upon review of relevant literature, interviews with industry experts, and similar measures. So while the model contains a significant number of values that are uncertain, these values are unlikely to be highly inaccurate. For example, it is highly unlikely that the average distance from the mailer to the Postal Service point of entry for mail is 50 miles rather than the 5 miles we have assumed, and it also is unlikely that any significant quantity of mail (or components) is transported following recycling or disposal by the recipient by any vehicle other than a large truck (collection or haul truck).[5] Accordingly, while our modeled results cannot be considered to be precise, we believe that they are accurate within a range that is typical of policy models, i.e., a factor of 50 to 100 percent. If anything, our deliberately conservative estimates and overall approach are likely to overstate the overall energy consumption, waste, and emissions from the mail stream, though by an unknown margin.

IV. Preliminary Model Results and Interpretation

We have used the model described above to perform some preliminary analysis of the four major mail Classes that account for the vast majority (more than 98 percent by volume) of the mail handled by the Postal Service. We also have attempted to better understand these results and put them into context by conducting a set of comparisons with other data and analytical results. Our results and our interpretation of them follow.

[4] In fact, like many analyses, our results are displayed showing a number of significant places not because the results are significant to that may places, but rather to allow checking of computations and calculations.
[5] The one exception applies to recycled and recovered materials, which may be transported by rail after they are separated and packaged at the Material Recovery Facility (MRF).

Preliminary Results

We have conducted preliminary runs of the LCI model using the data described above and previously discussed. Summaries of major model results are provided in Exhibits 7 through 10. Exhibit 7 displays selected results addressing waste generation and pollutant emissions on a unit basis, using the functional unit employed in the model – one million mail pieces. Exhibit 8 provides analogous results for energy consumed according to major use.

Exhibit 7
Preliminary Life Cycle Inventory Model Results – Major Mail Products
Waste Generation and Pollutant Emissions-Unit Basis

Mail Product	Total Life Cycle Stage Waste & Emissions (kg/million pieces)				
	Solid Waste	Dissolved Solids	Hydrocarbons	Particulate Matter	Carbon Dioxide Equivalent
First-Class Mail	20,629.56	257.88	487.40	80.62	87,106.08
Standard Mail	54,124.99	614.00	620.30	198.99	162,391.23
Periodicals	212,122.34	2,267.96	5,709.66	872.40	744,465.89
Package Services	209,147.71	4,444.79	2,471.10	831.27	1,210,708.29
Other Mail Products[a/]	4,957.47	1,409.94	2,313.27	127.53	913,900.50
Special Services[a/]	1,295.36	648.54	215.29	5.41	282,299.51

[a/] Postal Service portion of life cycle only.

Exhibit 8
Preliminary Life Cycle Inventory Model Results – Major Mail Products
Energy Consumption-Unit Basis

Mail Product	Total Life Cycle Stage Energy Consumption (MM BTUs/million pieces)		
	Transportation	Facility Operation	Total
First-Class Mail	269.08	1,292.30	1,561.39
Standard Mail	381.53	2,870.28	3,251.80
Periodicals	1,245.39	12,435.85	13,681.24
Package Services	8,863.96	10,287.98	19,151.94
Other Mail Products[a/]	11,901.11	2,003.04	13,904.15
Special Services[a/]	297.43	5,507.12	5,804.55

[a/] Postal Service portion of life cycle only.

These results show that waste and emissions on a unit (piece) basis vary substantially across the four major mail classes examined here. Periodicals and, particularly, Package Services, mail cause roughly an order of magnitude greater waste generation, pollutant emissions, and energy consumption than do First-Class and Standard Mail. This marked difference is primarily attributable to the relative weights (mass) of the typical mail piece within each class. Heavier mail pieces require proportionately more fuel to transport and deliver, and pollutant emissions are primarily a function of energy use within the context of the mail's life cycle. Another important factor in explaining the observed differences among the four mail products is the relatively large amount of printing and pages in a typical periodical in comparison with other mail products. This results in substantially higher unit facility energy consumption, solid waste generation, and hydrocarbon emissions for periodicals than one would otherwise expect, based upon product weight or density alone.

Another interesting observation is that the "other mail products" category accounts for the largest share of energy consumed from transportation and the second largest share of overall CO_2 emissions, despite that fact that the model does not consider the life cycle stages of these products outside of the Postal Service. This large share is attributable to the overwhelmingly large share of the jet fuel that is distributed to this category[6] and the relative per-piece efficiencies of transporting mail via aircraft.

Exhibits 9 and 10 provide the results of Exhibits 7 and 8, respectively, in the aggregate, that is, for the total number of mail pieces of each major product, as of FY 2006. From this point of view, patterns evident on a unit basis change considerably, because of the relative volumes of First-Class and Standard Mail as compared with Periodicals and, particularly, Package Services. Standard Mail now accounts for the largest share of energy consumption, waste, and emissions across the board, while levels for Package Services are an order of magnitude lower than those of the other major mail products for many of the indicators of interest.

Exhibit 9
Preliminary Life Cycle Inventory Model Results – Major Mail Products
Waste Generation and Pollutant Emissions-Total

Mail Product	Total Life Cycle Stage Waste & Emissions (MT)				
	Solid Waste	Dissolved Solids	Hydrocarbons	Particulate Matter	Carbon Dioxide Equivalent
First-Class Mail	2,013,752	25,173	47,577	7,870	8,502,785
Standard Mail	5,545,622	62,910	63,555	20,389	16,638,534
Periodicals	1,913,887	20,463	51,516	7,871	6,716,990
Package Services	245,654	5,221	2,902	976	1,422,035
Subtotal	**9,718,916**	**113,767**	**165,551**	**37,106**	**33,280,344**
Postal Service Share of Above	25,031	8,551	9,933	877	4,832,408
Other Mail Products	14,219	4,044	6,635	366	2,621,286
Special Services	1,967	985	327	8	428,707
USPS Institutional	15,035	3,624	5,576	347	3,051,061
Total for USPS	**56,252**	**17,204**	**22,471**	**1,597**	**10,933,462**

The share of each pollutant that is attributable to Postal Service operations is highly variable, though limited. For all parameters except carbon dioxide, the share is ten percent or less of the total. The Postal Service's share of CO_2[7] is 14.5% of the total, while for several other parameters, it is less than five percent: SO_x (4.0 percent), particulate matter (2.4 percent), and solid waste (0.3 percent). In all cases, the vast majority of the remainder is attributable to the paper and board manufacturing, printing/ mail production, and, for both solid waste generation and carbon dioxide emissions, the landfill disposal life cycle stages. For most endpoints considered by the LCI model, the paper and board manufacturing stage of the mail life cycle dominates all subsequent stages. The relatively high contributions for both this stage and for Postal Service operations are likely due to full consideration of fuel use both in transportation and facility operation within the model for these two stages, as emissions of most of the pollutants profiled here are closely and directly proportional to fossil fuel use.

[6] The category includes Priority Mail and Express Mail. These two products account for about 55 percent of all air transport costs, and hence are assigned a like percentage of jet fuel consumption.
[7] In this LCI model, CO2 emissions include the CO2-equivalent emissions of other significant global warming gases such as methane and nitrous oxide where data are available.

Exhibit 10
Preliminary Life Cycle Inventory Model Results – Major Mail Products
Energy Consumption-Total

Mail Product	**Total Life Cycle Stage Energy Consumption (MM BTUs)**		
	Transportation	**Facility Operation**	**Total**
First-Class Mail	26,266,490	126,146,878	152,413,368
Standard Mail	39,091,108	294,087,259	333,178,366
Periodicals	11,236,610	112,203,273	123,439,882
Package Services	10,411,155	12,083,731	22,494,885
Subtotal	87,005,362	544,521,140	631,526,502
Postal Service Share of Above	46,088,274	35,532,868	81,621,142
Other Mail Products	34,135,233	5,745,203	39,880,435
Special Services	451,692	8,363,248	8,814,939
USPS Institutional	21,636,874	24,093,139	45,730,012
Total for USPS	**102,312,073**	**73,734,457**	**176,046,529**

This conjecture is borne out by examination of the data in Exhibit 10, which show that energy used for facility operation relative to that used for transportation dominates overall and for three of the four major Postal products. Transportation energy accounts for 46 percent of the life cycle energy used in Package Services. This is likely due to the proportionately greater weight of Package Services mail pieces relative to that of other mail products. As discussed above, greater weight implies greater transportation fuel use.

Some further perspective on solid waste generation and management is provided by Exhibits 11 and 12. Exhibit 11 shows the percentages and quantities of material recovered from the mail and returned to product manufacturing following its receipt and use. Exhibit 12 displays the quantities of material generated, collected, and sent to ultimate end-of-life disposition at several major life cycle stages and in total. Total quantities of material displayed here include only the components of the mail and materials generated within the Postal Service associated with handling and transporting the mail. Solid wastes generated by other major life cycle stages (e.g., paper manufacturing, production of fuels) are included in the summary data presented in Exhibits 7 and 9.

Exhibit 11

End of Life Management of Mail Following Use - Recycling

Mail Product	**Recycling Rate**	**Quantity Mail Recycled (metric tons)**	**Quantity of Material Recovered (metric tons)**				**Percent of Original Mail Mass**
			Paper	**Board**	**Plastics**	**Total Recovered Material**	
First Class - all	45.0%	893,433.7	700,498.7	0.0	21,351.4	721,850.1	36.7%
Standard Mail	45.0%	2,403,370.3	1,903,277.0	40,069.0	58,466.2	2,001,812.1	37.9%
Periodicals	45.0%	825,004.9	650,684.6	0.0	14,626.3	665,310.9	38.2%
Package Services	45.0%	105,961.4	18,611.5	46,528.8	10,772.7	75,913.1	32.2%
All Four Products	45.0%	4,227,770.1	3,273,071.8	86,597.8	105,216.6	3,464,886.2	37.5%

Exhibit 12

End of Life Management of Mail Following Use - Energy Recovery and Disposal								
		Quantity of Material (metric tons)						Percent of Original Mail Mass
Mail Product	Mail Recipient Discard Rate	Mail Discarded by Recipients	Residual Material Following Recovery	Packaging & UAA Mail Discarded by USPS	Material to Waste-to Energy	Material to Landfill Disposal	Total Material to WtE or Landfill	
First Class - all	55.0%	1,091,974.5	171,643.1	4,567.9	196,395.7	1,081,609.7	1,278,005.3	65.0%
Standard Mail	55.0%	2,937,452.5	502,499.7	241,108.8	569,294.6	3,140,231.2	3,709,525.8	70.2%
Periodicals	55.0%	1,008,339.3	164,644.0	11,959.4	182,740.1	1,011,339.6	1,194,079.7	58.1%
Package Services	55.0%	129,508.3	40,408.9	24,201.5	27,530.1	167,965.2	195,495.3	71.3%
All Four Products	55.0%	5,167,274.6	879,195.7	281,837.7	975,960.4	5,401,145.7	6,377,106.1	69.1%

These data show that, based upon the national averages used in this analysis, that substantial quantities of mail are recycled and returned to productive use. We estimate that the material recycled and ultimately recovered from the mail stream is nearly 3.5 million metric tons per year. In contrast, more than 6.1 million metric tons are either sent to disposal in a landfill or are directed to a waste-to-energy facility. Total quantities of material sent to final landfill disposal, including residues of recycling/recovery and waste-to-energy conversion, exceed 6.3 million metric tons.

Sensitivity Analysis

As discussed above, we have chosen a distribution mechanism that allocates fuel used by the Postal Service to individual mail products and to institutional, or network, uses. This mechanism uses causal relationships between the activities that give rise to fuel use and the functional unit to distribute shares of the use of each fuel type, as stipulated by the ISO Standard. Because the shares differ markedly across mail products and also across Postal Service activities, we have performed a sensitivity analysis to examine the impact of using some alternative allocation mechanisms. Specifically, we have calculated resource use and related emissions by mail product based on mail product pieces, weights, and volumes (three-dimensional volume, or "cube"). The results for one endpoint of interest (CO_2-equivalent emissions) appear in Exhibit 13 below. We have chosen this parameter due to the significant attention and interest being devoted to carbon emissions and climate change in both the public policy and corporate spheres.

This exhibit shows that the estimated fuel and pollutant emissions associated with each mail product differ markedly depending upon the distribution key chosen. None of the three alternatives appears to have a consistent relationship to the baseline key, which is based upon underlying causal factors. Accordingly, none of these more simple, and perhaps, intuitively obvious alternatives appear to be a potentially suitable substitute for the method that we have employed. It should be noted, however, that regardless of which distribution key is chosen to allocate USPS fuel use and related emissions among mail products, this choice has only limited impact on the overall results of the analysis. This is because the life cycle stages involving the Postal Service and its activities account for a relatively minor share of the life cycle total for most endpoints of interest.

Exhibit 13
Preliminary Life Cycle Inventory Model Results – Major Mail Products
Sensitivity of Results to Allocation Method for USPS Energy: CO2

Sensitivity Analysis - Significance of the Choice of Distribution Keys for Allocation of USPS Fuel Use

		Estimated CO_2-Equivalent Emissions (metric tons)								
Distribution Key	**Life Cycle Stages**	**First Class - all**	**Standard Mail**	**Periodicals**	**Package Services**	**All Four Products**	**All other USPS Products**	**Special Services**	**U.S. Postal Service-Institutional**	**Total Emissions**
Resource usage (baseline)	USPS	2,377,603	1,371,945	399,557	683,303	4,832,408	2,621,286	428,707	3,051,061	10,933,462
	Outside	6,125,182	15,266,589	6,317,433	738,733	28,447,936				28,447,936
	Total	8,502,785	16,638,534	6,716,990	1,422,035	33,280,344				39,381,398
Pieces	USPS	3,584,469	3,762,397	331,316	43,130	7,721,312	105,324	55,765	3,051,061	10,933,462
	Outside	6,125,182	15,266,589	6,317,433	738,733	28,447,936				28,447,936
	Total	9,709,651	19,028,986	6,648,748	781,863	36,169,248	105,324	55,765	3,051,061	39,381,398
Weight	USPS	1,330,111	3,578,048	1,228,236	1,051,675	7,188,070	694,331		3,051,061	10,933,462
	Outside	6,125,182	15,266,589	6,317,433	738,733	28,447,936				28,447,936
	Total	7,455,292	18,844,637	7,545,669	1,790,408	35,636,007	694,331	-	3,051,061	39,381,398
Volume (cube)	USPS	1,018,597	2,023,467	670,756	2,206,249	5,919,069	1,963,332		3,051,061	10,933,462
	Outside	6,125,182	15,266,589	6,317,433	738,733	28,447,936			-	28,447,936
	Total	7,143,778	17,290,056	6,988,189	2,944,982	34,367,006	1,963,332	-	3,051,061	39,381,398

Divergence of USPS Fuel Allocation and Related CO_2-Equivalent Emissions from Baseline (percent)

Distribution Key	**First Class - all**	**Standard Mail**	**Periodicals**	**Package Services**	**All Four Products**	**All other USPS Products**	**Special Services**	**U.S. Postal Service-Institutional**	**Total Emissions**
Pieces	50.8%	174.2%	-17.1%	-93.7%	59.8%	-96.0%	-87.0%		0.0%
Weight	-44.1%	160.8%	207.4%	53.9%	48.7%	-73.5%			0.0%
Volume (cube)	-57.2%	47.5%	67.9%	222.9%	22.5%	-25.1%			0.0%

Another issue that could conceivably limit the accuracy and utility of our results is the possibility that we have not included life cycle stages, activities, or phenomena that would contribute impart substantial changes to the estimates generated by the model. There are several issues that have been raised in peer review of the model that may be important in this regard. These are discussed below in turn.

The first is whether by beginning the life cycle inventory at the point at which trees are harvested, our modeling approach ignores the waste generation, fuel consumption, and pollutant emissions associated with growing trees. In addition, this approach neglects the carbon sequestration function that growing trees provide.[8] We did not include silviculture as a life cycle stage in the model due to an absence of the necessary data. We do not have reason to believe, however, that the materials used to plant and grow trees (e.g., fertilizers, pesticides) or the fuels required to prepare the land, plant the trees, and maintain them until harvest are significant relative to those of the downstream life cycle stages. The carbon uptake issue is, however, worthy of closer examination.

Living trees and forests remove CO_2 from the atmosphere to produce new wood on an ongoing basis during the growing season. The rate at which this occurs is highly variable and depends upon such factors as climate, soil conditions, species (or forest species composition), and tree (or stand) age. Because the carbon stored in a harvested tree is embodied in the wood and addressed elsewhere (generally, at end-of-life management) in the life cycle by the model, the real question is the magnitude of the additional carbon that would have been sequestered by the tree had it not been cut.

Data collected and reported by the U.S. Forest Service provide some context for this question. Since 1952, when national statistics were first reported, forest growth in the United States has exceeded the rate of harvest. On commercial forestland, net annual growth surpasses the rate of harvest by almost 50 percent. In fact, the "forest inventory" in the US has grown by 39 percent since 1953, according to the US Forest Service.[9] This growth in forested area continues, even as our population and the economy expand; the U.S. has increased its forested land by an average of nearly 400,000 acres per year on a net basis from 2000-2005.[10] Part of what accounts for this continued growth in forested land is the standard industry practice of replanting following harvest. This helps to ensure a perpetual source of new wood fiber, and means that carbon sequestration activity performed by harvested trees is replaced by carbon sequestration activity in the trees planted to replace those harvested. Any net impact on sequestration is then simply any differential rate of carbon capture between the harvested and newly planted trees. We do not have reason to believe that this differential is large relative to other factors that have been shown to affect tree growth and, therefore, carbon sequestration.

Nonetheless, we have examined this question empirically by obtaining data published by the U.S. EPA on carbon sequestration rates and on the characteristics of U.S. timber lands used to produce trees for paper and board production ("pulpwood"). Using these data, we have estimated a range for the annual incremental carbon sequestration that has been lost due to the harvesting of the trees needed to produce one average ton of paper in the U.S. These data are presented in Exhibit 14. These data indicate that even under conservative assumptions, the quantity of new CO_2 sequestration lost is about 0.44 tons (0.40 metric tons) per ton of paper per year.

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[8] Note that such upstream issues are less prominent or non-existent for other raw materials (e.g., petroleum, minerals) that are used to produce or process mail components.

[9] USDA Forest Service, "Forest Resources of the United States, 2002" (Smith, et. al.), http://www.ncrs.fs.fed.us/pubs/gtr/gtr_nc241.pdf; Sustainable Forestry Initiative® Program, http://www.aboutsfi.org; cited on Abundant Forests Alliance, "Environmental Myths & Facts," http://www.abundantforests.org/press_eiq_facts_3.html

[10] United Nations Food and Agriculture Organization (FAO), 2007. *State of the World's Forests 2007*. Rome, pg. 115.

Exhibit 14

Carbon Sequestration Foregone through Pulpwood Harvested to Produce Mail-U.S. National Average (per ton paper)						
	Tons Carbon/year			Tons CO_2/year		
	Low End	Average	High End	Low End	Average	High End
Harvest of 100% of Tree Cover	0.013	0.051	0.090	0.047	0.188	0.330
Harvest of 75% of Tree Cover	0.017	0.069	0.120	0.063	0.251	0.440

If one assumes – contrary to fact – that this sequestration potential is not replaced by newly planted (replanted) trees, and then applies these rates to the quantities and composition of the mail as detailed in the LCI model, one can estimate the upper bounds of potential lost carbon sequestration potential associated with producing the mail. We have calculated these estimates, which are presented in Exhibit 15.

Exhibit 15

Foregone Carbon Sequestration Embodied in the Mail						
	Metric Tons CO_2 Equivalent			Percentage of LCI CO_2 Equivalent Emissions Predicted by LCI Model		
Mail Product	Low-End, 100% Harvest	Average, 75% Harvest	High-End, 75% Harvest	Low-End, 100% Harvest	Average, 75% Harvest	High-End, 75% Harvest
First Class - all	82,253.2	438,683.5	767,696.1	1.0%	5.2%	9.0%
Standard Mail	219,006.3	1,168,033.5	2,044,058.7	1.3%	7.0%	12.3%
Periodicals	72,884.5	388,717.3	680,255.3	1.1%	5.8%	10.1%
Package Services	7,038.4	37,538.2	65,691.8	0.5%	2.6%	4.6%
All Four Products	381,182.3	2,032,972.5	3,557,701.9	1.1%	6.1%	10.7%

These data show that the range of CO_2 sequestration foregone runs from about one percent to nearly eleven percent of the LCI CO_2 emissions calculated for the four major mail products. In the example of First Class Mail, we have estimated that the 97,614 million pieces of this mail contain 1.925 million tons of paper and paper board. Multiplying the two yields an estimated quantity of CO_2 sequestration foregone attributable to First Class Mail of about 768 thousand tons. This is equivalent to nine percent of the total (8,502,785 metric tons) estimated by the LCI model for the balance of the life cycle. Use of the average value and the assumption of full harvesting of tree cover (a common practice) would reduce this estimate to three percent of the total. Applying this method to the other mail classes yields estimates of a similar magnitude except for Package Services. The difference is attributable to the fact that First Class, Standard, and Periodicals mail is, on average, of lighter weight and is highly paper-intensive, while Package Services is, on average, heavier and the least paper-intensive mail type. In any event, given that replanting of harvested lands is very common in the U.S., it is likely that viewed from a full life cycle perspective, the lost CO_2 sequestration reported here is overstated or even, effectively, zero. As stated above, actual carbon capture rates are a function of many site-specific variables, so the magnitude of any such overstatement would be very difficult to estimate on a nationwide basis.

A second possible concern also pertains to where we have drawn the boundaries in defining and populating our life cycle inventory. We have expressly limited the scope of the analysis to the creation, processing, delivery, and post-use management of the mail, and have not extended the analysis to consider the manufacturing of capital equipment, construction of buildings, employee commuting, and similar secondary and tertiary considerations. We believe that this approach is reasonable and consistent with the manner in which most corporate organizations assess and manage their environmental aspects. In addition, as a practical matter, one must limit the scope of a life cycle inventory to enable its completion within a reasonable period of time and expenditure of resources. Moreover, when applied to the functional unit defined in this analysis, some preliminary calculations suggest that the incremental contribution to the endpoints considered here made by including the environmental aspects of building and installing long-lived assets such as mail handling equipment and buildings would be very small. Employee commuting is an interesting issue, and given the large size of the Postal Service's work force, this issue could conceivably affect our results in material ways. For the present, this remains an issue for further assessment.

Finally, reviewers have raised the issue of customer travel to USPS facilities (Post Offices) to enter and receive mail, and questioned whether our model takes this activity fully into account. While we have explicitly embodied a conservative assumption to account for customer entry of mail (five mile distance to the local Post Office), we have not accounted for those customers who travel to the Post Office to pick up their mail. In theory, the miles that these people travel and the related fuel consumption and pollutant emissions) should be reflected in our modeling approach. At present, we do not have the data to perform the analysis, so this too remains an issue for further development.

Comparisons of LCI Model Results with Other Data and LCI Studies

As one means of interpreting and validating our preliminary LCI model results, we have conducted some limited comparisons of our results with nationwide statistics for industry-wide and personal energy consumption, CO_2 emissions, solid waste generation, and other example indicators. The purpose of these comparisons is not to develop or support any contention that the mail stream does or does not have higher or lower resource consumption or pollutant emissions than other alternative means of delivering messages, information, and/or goods. It simply is a means of helping us to understand the realism of our preliminary model results. On that score, the comparisons described below suggest that our results are reasonable and realistic, i.e., emissions, waste, and energy use estimates are within a range that seems credible.

These comparisons, organized by model endpoint, are presented below. We begin with some data that help to put the energy consumption, waste generation, and pollutant emissions estimated by the LCI model as attributable to the mail into context by assessing the scale, or overall importance of the mail's resource consumption and emissions, relative to the U.S. as a whole. This is done by comparing the results for the four major mail classes in the aggregate to U.S. national data for major industries and sectors of the economy. We then present some preliminary results drawn from other sources that address different types of mail products and services and compare them to our model estimates for the appropriate class(es) of mail. Comparisons are made with as many different model endpoints as the data will support.

<u>Scale of Mail-Related Emissions</u>

Energy Consumption

Total energy consumed by the four mail products accounts for 0.6% of national energy consumption. The total estimated life cycle energy consumption for the four major mail products examined in the initial application of the LCI model is about 632 trillion BTU, which is about 0.6 percent of the national total. About 78 percent of this energy is consumed in the paper and paper board manufacturing process. The portions of the product life cycle downstream of the manufacture of the mail's "raw materials" consume about 136 trillion BTUs for the four major mail classes combined.

For comparative purposes, consider the energy consumed by other industries and economic activities, as illustrated by the following data. Total manufacturing energy use (2002 data) in the U.S. is (was) 22,666 trillion BTUs. Major contributors to the manufacturing energy use national total include petroleum (6,799 trillion BTUs), chemicals (6,465 trillion BTUs), paper (2,363 trillion BTUs), part of which is accounted for by the model, and primary metals (2,120 trillion BTUs).[11] The 496 trillion BTUs consumed by the manufacture of paper and board used in the mail make this life cycle stage comparable to a number of other resource-intensive industries, such as the production of nitrogenous fertilizer (497 trillion BTUs), alumina and aluminum (473 trillion BTUs), and cement (409 trillion BTUs).

The total estimated life cycle energy consumed by the four major mail products downstream of paper and board production can also be compared with other commercial, rather than industrial, uses of energy. Most of this energy is used to condition (i.e., heat, cool, and ventilate) buildings. The 136 trillion BTUs consumed in the aggregate to make, deliver, and manage the mail following use is less than the energy used in all of the major categories of building use defined and quantified by the U.S. Department of Energy's Energy Information Administration (EIA), but is closest to the total national building energy consumption for public order and safety (209 trillion BTUs), outpatient health care (247 trillion BTUs), and religious worship (288 trillion BTUs).[12]

Carbon Emissions

Total greenhouse gas emissions attributable to the four mail products accounts for a fraction of one percent of national CO2 emissions. The LCI model estimates that total life cycle carbon emissions (CO2 equivalents) attributable to the four major mail products examined here is 33,280,344 metric tons (MT) as of FY 2006. The national U.S. total for anthropogenic emissions of greenhouse gases in 2006 was 7,075.6 *million* metric tons.[13] Thus, the roughly 33 million metric tons of CO_2-equivalent emissions emitted over the life cycle of the four mail Classes comprise 0.47 percent of the national total.

By comparison, CO_2 emissions from industrial sources in the U.S. are generally far higher, led by petroleum (304.8 million MT), chemicals (311.0 million MT), and primary metals (212.8 million MT). Total emissions from the pulp and paper industry, which are partially captured in the model results, amount to 102.4 million MT annually.[14] Note that these data address energy-related CO_2 emissions only.

Commercial sector CO_2 emissions amounted to 1,045.2 million MT in 2006, most of which was attributable to electricity use, while total industrial CO_2 emissions were 1,650.8 million MT; transport-related emissions were 1,990.1 million MT.[15] Accordingly, if end-to-end mail creation, transport and delivery, and disposition were to be included in any of these major sectors (note that it has elements of each), it would account for between 1.7 and 3.2 percent of the national sector total, according to our model. And if it were compared to the sum of the three, it would comprise 0.7 percent of the national total.

Some additional perspective can be gained by comparing mail-related CO_2 emissions to those of a typical U.S. household or individual in carrying out some of the activities of day to day living. Exhibit 16

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[11] Energy Information Administration, 2007. *2002 Energy Consumption by Manufacturers--Data Tables*. Table 1.1 First Use of Energy for All Purposes (Fuel and Nonfuel), 2002.

[12] Energy Information Administration, 2006. *2003 CBECS Detailed Tables*. Table C1A. Total Energy Consumption by Major Fuel for All Buildings, 2003.

[13] Energy Information Administration, 2007. *Emissions of Greenhouse Gases in the United States 2006.* Washington, DC. Report #DOE/EIA-0573(2006). Pg. 1.

[14] Schipper, M., 2006. *Energy-Related Carbon Dioxide Emissions in U.S. Manufacturing*. Washington, D.C. Energy Information Administration (EIA). Report #DOE/EIA-0573(2005). Pg. 4.

[15] Energy Information Administration, 2007. *Op cit*. Pp. 13-15.

provides a summary of the total and unit CO_2 emissions for the four major mail products and in total, as estimated by the LCI model.

These per household and per person CO_2 emission rates can then be compared with the emissions that result from a variety of activities that take place in typical U.S. homes. On an overall basis, U.S. EPA data[16] show that the average American household is responsible for the emission of 18.8 metric tons of CO_2 annually. Of this total, about 7,400 kg arises from the generation of the electricity that is used in the home, almost 5,000 kg is from the use of natural gas, and almost 5,500 is due to automobile use. In comparison, only one of the four major mail products examined in this LCI generates CO_2 at even one percent of the level of any of these major categories of household fuel use, and the total emissions from the four major mail products received by the typical household is less than four percent of that associated with the lowest-emitting utility (natural gas use, at 5,000 kg/year). In fact, it is only one percent of the total household emissions from the sum of these major categories.

Exhibit 16
Estimated Major Mail Product CO_2 Emissions

Greenhouse Gas Emissions (CO_2 Equivalents)	Mail Class				
	First Class	Standard	Periodicals	Package Services	Total
Total (MT)	8,502,785	16,638,534	6,716,990	1,422,035	33,280,344
Per million pieces (kg)	87,106	162,391	744,466	1,210,708	158,274
Per piece (g)	87.1	162.4	744.5	1,210.7	158.3
Annual per household (kg)[a/]	45.2	103.9	43.9	23.0	195.8
Annual per person (kg)[b/]	28.3	55.4	22.4	4.7	110.8

[a/] Household mail quantities obtained from USPS, 2007. *The Household Diary Study: Mail Use & Attitudes in FY 2006*. March. Contract #2APSER-05-B-3122. Table 1.6.
[b/] Population data as of 1 January 2007. Obtained from U.S. Bureau of the Census.

Exhibit 17 provides some calculated CO_2 emission rates from a variety of individual activities that are common in the U.S. These data provide some further context for understanding the magnitude of the carbon footprint associated with the four major mail products profiled here.

Mail-related CO2 emissions are less than those of many individual daily activities. As shown in Exhibits 16 and 17, the total life cycle CO_2 emissions from one person's mail (700 pieces per year) are roughly equivalent to the fuel combustion-related emissions (from power generation) from using a clock radio for the year plus taking one airplane flight during the year or using gas-powered lawnmower. At the household level, annual CO2 emissions from the mail are roughly equivalent to those from using a variety of common household appliances (e.g. coffee maker, clothes dryer) regularly over the same interval.

[16] Source: http://www.epa.gov/climatechange/emissions/ind_calculator.html. Note that it is unclear whether or not EPA's emissions data include pre-combustion emissions.

Exhibit 17
CO_2 Emissions from Personal Activities in the U.S.[a/]

GHG Emissions from personal activities:[3/]	Appliance power (watts)	Operating period (hours/week)	Power Consumed/ week (watt-hours)	Power Consumed/ year (kWh)	Annual CO_2 Emissions (kg)
Using a coffee maker for one hour every day for one year	1050	7	7350	382.2	236.3
Operating an electric clothes dryer (3400 W) two hours per week for one year	3400	2	6800	353.6	218.6
Operating a dishwasher three times per week for one year	1800	3	5400	280.8	173.6
Operating a personal computer and monitor 20 hours per week for one year	270	20	5400	280.8	173.6
Operating a 5 hp lawnmower - 25 times, at 60 minutes each time (kg)					57.8
Using a clock radio for one year	10	168	1680	87.36	54.0
One ~~airplan~~airplane flight: (Per person CO2 emissions, 500 mile flight with 200 people aboard)[4/]					49.7

[a/] Except as noted, USDOE, 2007. Estimating Appliance and Home Electronic Energy Use. Obtained from http://www.eere.energy.gov/consumer/your_home/appliances/index.cfm/mytopic=10040.
[b/] Calculation using http://www.etc-cte.ec.gc.ca/databases/lawnmoweremissions/default.aspx
[c/] Derived from USEPA, 1999. Evaluation of Air Pollutant Emissions from Subsonic Commercial Jet Aircraft. Office of Air and Radiation. Doc. No. EPA420-R-99-013. April.

Solid Waste Disposal

According to the LCI model, the four mail products reviewed in our analysis and their components account for about 13 percent of the paper and paper board that is discarded annually in the U.S. Total estimated solid waste generated through the life cycle of the four major mail products is about 9.7 million metric tons in FY 2006. Approximately 56 percent of this total is attributable to post-use management of the mail product, with most of the remaining 44 percent or so attributable to the manufacture of the materials comprising the mail piece. According to the LCI model, the quantity generated downstream of the paper/board mill and printer (hence, likely to be disposed as municipal solid waste) is 5.6 million metric tons. The vast majority of this material is wasted paper and board, along with, for a fraction, end-of-life combustion residues. According to the most recent U.S. EPA data,[17] a total of 41.26 million tons of paper and board were wasted in 2006, with 24.68 million tons of that being non-durable paper and board products. Therefore, the discarded post-use components of the U.S. mail stream, as characterized by the four major mail products, account for 13 percent of the paper and board contained in the municipal solid waste stream, as of 2006.

As discussed above, these quantities reflect the materials reporting to landfill disposal (about 82 percent) or to waste-to-energy facilities for energy recovery (about 18 percent). In addition, about 45 percent of the mail and other materials discarded post-use are recycled, with the vast majority assumed to be recovered and returned to productive use. According to the model and based upon U.S. EPA data, we

[17] U.S. EPA, 2007. *Municipal Solid Waste in the United States: 2006 Facts and Figures-Data Tables*. Office of Solid Waste, EPA-530-F-07-030. November. Table 4.

estimate that nearly 3.5 million metric tons, or 37.5 percent of the original mail stream, are recovered rather than disposed.

Product-Level Comparisons

Solid Waste Disposal

The estimated quantities of solid waste generated by the Standard Mail and Periodicals classes as predicted by the model are in general agreement with published EPA figures for 2006. EPA provides a figure of 2.52 million tons of magazines being discarded following use, with 1.55 million tons being wasted (not recovered). This includes magazines from newsstand sales, which are not mailed, of about 13 percent of the total.[18] By comparison, the LCI model reports solid waste reporting to disposal following use of 1.01 million metric tons (1.11 million short tons). For Standard Mail, EPA reports 5.83 million tons entering the solid waste stream and 3.74 million tons being disposed, while the model estimates total solid waste disposal of 3.14 million metric tons (3.46 million short tons) following use. Directly comparable EPA data are not available for the other two major mail products examined in this initial analysis.

Energy Consumption

Another basis of comparison is provided by the recently published corporate sustainability report issued by UPS, Inc., a major competitor to the Postal Service in its Package Services business line. A review and comparison of some of the pertinent data within this report with our initial LCI modeling results yields several interesting findings.

When compared on an equal footing, our modeled energy consumption results closely parallel the publicly reported energy consumption of a major Postal Service competitor, and major differences can be explained by the mix of transportation modes used by each company. The recently published corporate sustainability report issued by UPS, Inc. provides data on several parameters of interest to this study, notably energy consumption and greenhouse gas emissions. The Service handles about one-third as many packages through its Package Services business as does UPS, and consumes about one-third as much facility energy as UPS, when the two are compared on the basis of their respective package delivery businesses. The Postal Service, however, consumes only about one-tenth as much transportation energy as ~~UPS,~~UPS and overall energy use by UPS exceeds that of the Postal Service by a factor of nine. On a per-package basis, the ratio is more than three to one. A likely explanation for this is that UPS makes far more extensive use of air transportation for its packages than does the Postal Service in its Package Services product. A comparison of the two services on the basis of revenue shows that Package Services consumes 4.78 GJoules per thousand dollars of revenue, while UPS consumes only 3.22 GJoules per thousand dollars of revenue.

Greenhouse Gas Emissions

Modeled CO_2 emissions differ substantially from those reported by a major Postal Service competitor, presumably as a function of differences in transportation mode. When compared on an equivalent basis, however, they are similar. Once again, the 2007 corporate sustainability report issued by UPS, Inc. provides data on an environmental aspect of interest here, greenhouse gas emissions. Many of the similarities and differences between UPS and USPS Package Services regarding energy consumption noted above are reflected, and in some cases, amplified when one compares carbon emissions. Total UPS CO_2 emissions exceed the modeled emissions of the Postal Service's Package Services business by a factor of almost 11, and on a per-package basis, by a factor of about 3.6. This is

[18] Magazine Publishers of America (MPA), 2006. *The Magazine Handbook 2006/07*. Washington, DC. Pg. 11.

likely due to the more extensive use of air transportation by UPS, as suggested above. When carbon emissions are normalized by revenue, however, the two services are far more similar; Package Services emits 29.74 metric tons of CO_2 per 100,000 dollars in revenue according to the LCI model, and UPS reportedly emits 24.20 metric tons.

Estimated life cycle emissions of greenhouse gases (GHG) from Periodicals (3.66 tons CO_2/ton Periodicals) are roughly three times recently published emissions for two major magazines (weighted average of 1.17 tons CO_2/ton magazines). An additional, though more limited, comparison may be drawn between our estimate of life cycle greenhouse gas emissions and those from another recent study.[19] This study catalogued the production, use, and post-use history of two magazines, and developed a full, magazine-specific, life cycle inventory. The authors reported a range of 1.01 to 1.25 metric tons CO_2-equivalent per metric ton of magazines, with a weighted average value of 1.17. This study included magazines sold at the newsstand. In comparison, our LCI model yields a figure of 6,707,324 metric tons of CO_2-equivalent emissions as of FY 2006. Dividing this number by the total weight of this mail product (2,020,345 tons) and adjusting to express the numbers in consistent units yields an emission factor of 3.66 metric tons CO_2-equivalent per metric ton of mailed periodicals. Sixty one percent of this total is attributable to the paper manufacturing life cycle stage, and an additional 21 percent is attributable to the periodical printing and preparation stage. The authors of the study of the two magazines reported a similar proportion of total CO2 emissions to be attributable to pulp and paper manufacture and related activities (61 and 77 percent), though the absolute quantities were considerably smaller.

In summary, we have sought out and reviewed data and analysis from a number of different sources with which to perform some "reality checking" of our initial LCI modeling results. While not definitive, we believe that these comparisons, as described above, suggest that our results are reasonable and generally consistent with both our expectations and with the work of other investigators.

V. Significant Limitations and Possible Areas for Further Model Development

We believe that our LCI model addressing the U.S. mail represents an important step forward in our ability to understand the environmental and resource implications of the current mailing infrastructure in the U.S. It addresses all of the most environmentally important activities in the mail value chain, and provides at least some insights into the magnitude of mail-related aspects affecting all environmental media. That said, there are some important limitations associated with the model and our approach more generally. In this section, we identify some of these limitations, then discuss some of the areas in which some further analytical and data development activity could materially improve the accuracy and internal consistency of the model.

Model Limitations

As described earlier in this report, we are confident that we have valid data and methods with which to quantify the environmental aspects of many stages in the life cycle of the mail. There are, however, a few stages and activities for which our understanding and supporting data are more limited.

One is the printing and mail preparation stage. To build this initial version of the LCI model, we have employed and adapted detailed energy consumption and air pollutant emissions data developed by EPA that characterize, across a variety of printer sizes and configurations, the flexographic printing process. Because, however, this is only one of several printing processes that are commonly used to produce products that enter the mail, it would be desirable to obtain and incorporate data with which to calculate similar environmental endpoints for the other major printing processes in use. These include offset

[19] The Heinz Center, 2006. *Following the Paper Trail: The Impact of Magazine and Dimensional Lumber Production on Greenhouse Gas Emissions: A Case Study*. Washington, DC. Pg. 48.

lithography and rotogravure, among others. These processes may exhibit energy consumption and pollutant emissions patterns that are similar to those of the flexographic process, but in the absence of comparable empirical data or engineering estimates, we can not make an assumption either way.

In a similar vein, we have not characterized in any detail the mail preparation process itself, which may be important in evaluating the life cycle inventory for mail pieces that are mass-produced (e.g., most Standard Mail and Periodicals). Mail preparation for these products in many cases involves adhesive application and other activities that may give rise to environmental aspects (e.g., air pollutant emissions) that we have not quantified and included to this point. Whether or not any such aspects would rise to the one percent threshold that we have defined as our study boundary is unclear at this point.

We also have taken a simplified approach in developing our estimates of the environmental aspects arising from air transport of the mail. In short, there is no uniform or consistent set of air pollutant emission factors for commercial jet aircraft that are or might be used to carry mail. Instead, emission factors vary by aircraft type, size, configuration, and engine brand and model. To characterize in a fully accurate manner the aircraft-related emissions resulting from carriage of the mail, it would be necessary to have detailed information on the aircraft fleet carrying the mail and the distribution of mail carried on each aircraft type within the fleet, and to then perform modeling runs for each aircraft type/configuration/ engine combination that carries mail. We concluded that such an effort was beyond the scope of the current exercise and would be unlikely to yield new and better insights sufficient to justify the significant time and resources that would be required to generate them.

Instead, to build our LCI model, we have made limited use of the best available modeling framework for estimating aircraft emissions, obtained several needed estimates from published reports and from experts at the U.S. EPA, and made some simplifying assumptions. We have combined these in building the LCI model component to address aircraft emissions by formulating a scenario characterizing use of a “typical” aircraft on which mail is transported. This aircraft (Boeing 737 cargo plane) and set distance traveled (500 miles) is employed in the LCI model to estimate the fuel consumption and air pollutant emissions for all mail that is carried on aircraft.

At some point, we could attempt to improve the sophistication and accuracy of this approach by obtaining additional data on the numbers and types of aircraft that actually are used to transport mail and performing some model runs. The recognized state of the art in calculating fuel consumption and air pollutant emissions from aircraft is a model maintained by the Federal Aviation Administration (FAA) called the Emissions and Dispersion Modeling System (EDMS). This model has been endorsed by the EPA since 1993, and is used to support both EPA rulemakings and local (airport-level) plans to control aircraft-related environmental aspects. As suggested above, the effort involved to accomplish this might be substantial.

Data Limitations

In addition to some of the limitations of the model itself, there are several areas in which our initial analysis could benefit from more extensive or recent data. Perhaps the most significant of these is the distribution of distances over which mail or its components are transported. For the present, we have made some assumptions based upon working knowledge of the mail and how it is produced and moved. These assumptions could perhaps be validated or improved with some focused research (e.g., surveys). Alternatively, it may be possible to find some of the desired data from a review of the literature, though such a review is unlikely to yield complete or entirely consistent data across the mail life cycle steps of interest.

Another basic limitation of our data concerns the degree to which we have fully characterized the life cycle inventory of all important stages. While our data for the components of the mail stream (paper, board, plastics) and liquid fuels are quite comprehensive, the level of depth that we can bring to other materials and activities within our model is constrained by the absence of life cycle data. Some additional literature work and/or purchase of commercial LCI data (e.g., from specialty European providers) could help to address this inconsistency.

VI. PEER REVIEW

The results of Life Cycle Inventories heavily rely upon the assumptions and data contained in the predictive model. To help validate the general approach and the data and to ensure against any potential bias in this study, the US Postal Service chose to undergo a formal external peer review process. The Postal Service further believed that obtaining some external expert opinion regarding the model, its structure, and its underlying data might yield new and important ideas for improving the model's validity and utility as presented in this report and for enhancements that will occur in the future.

Three people with extensive experience and knowledge of environmental factors were engaged to form the Peer Review Panel (Panel):

- Valerie Thomas, Anderson Interface Associate Professor
    - School of Industrial and Systems Engineering, Georgia Institute of Technology

- Edwin Pinero, Director, Pollution Prevention Center
    - Golisano Institute of Sustainability, Rochester Institute of Technology

- Michael T. Huguenin
    - Industrial Economics, Incorporated, Cambridge, Massachusetts
    - (Formerly Executive Director of the Harvard University Center for Risk Analysis)

Each member of the Panel was provided a draft of the report, "The Environmental Impacts of the U.S. Mail: Initial Life Cycle Inventory Model and Analysis" along with a working copy of the spreadsheet model used to derive the inventory of impacts. Each member of the Panel was asked to review the report and model based upon their unique individual experience and comment upon the validity of the approach and the interpretation of the results as expressed in the report. The Panel was not asked to either verify the raw data used to populate the model or verify the formulas used in the model.

As an aid to the Panel, the authors of the report provided a list of questions that the Panel could consider in conducting the peer review. However, the Panel members were left to their own discretion as to how to make use of the questions during the review. The questions put forth by the authors were as follows:

- To your knowledge, is this model unique or do you know of other models/studies that examine the full life cycle inventory of the mail? Are there previous efforts that address particular mail products or portions of the life cycle? Please identify and describe any such studies or models.

- Based upon your knowledge and experience in applying life cycle inventory concepts, do you believe that in constructing the model, we have omitted any life cycle stages or activities that are likely to be important? If so, what are they and what underlies your belief that they are important given the defined scope and boundaries of this study?

- Do you believe that the model incorporates consideration of an appropriate set of endpoints (environmental aspects) given its intended purpose? If not, what constituents or other endpoints would you add, delete, or modify? If you recommend adding constituents, what sources would supply the necessary inventory data?

- ♦ What specific techniques, if any, would you recommend to improve the accuracy of the quantitative estimates of environmental aspects computed by the model? In your judgment, which model components are most well-developed and complete and which are most in need of further development?

- ♦ What additional sources of life cycle inventory or other data do you know of that could be drawn upon to supplement our existing information base? How can the data they contain be used most productively to improve our model?

Each member of the Panel submitted written comments that were then shared among the Panel members, the authors, and representatives of the US Postal Service. A face-to-face meeting was held in Washington, DC on April 7, 2008 that included the three members of the Panel, the primary authors, and the Postal Service sponsors. The meeting provided for a free exchange of ideas while ensuring clarity of the Panel's comments.

Overall, the consensus of the Panel was that the Report was well written and clear in terms of both the scope that was covered and the limitations that the authors faced. Significant topics of discussion included:

- ♦ The life-cycle boundaries, especially regarding forest management;
- ♦ The approach to allocating energy, relating to use of revenue/cost versus either mass or volume;
- ♦ The consideration of customer trips to a post office;
- ♦ The assumptions regarding recycling or non-recycling of discarded mail;
- ♦ The contrast between the validity/accuracy of the data with variability/uncertainty;
- ♦ The relationship of this report to other studies on the environmental impacts of the mail; and
- ♦ The impacts associated with other mail products not covered in this study.

Following this meeting, the authors revised the report to respond to a number of the issues raised by the Panel. The final draft of the report was resubmitted to the Panel to allow each member of the Panel to evaluate how the revisions addressed each of his or her comments. The Panel was asked to revise, edit, or expand upon their original comments based upon this final review.

The comments of each member of the Peer Review Panel are presented in Attachment B of this report and reflect the final thoughts of each member. The Panel has identified areas that project sponsors in the US Postal Service should keep in mind as they move forward with this report. While not an exhaustive list of what is reflected in the comments, reviewers identified several issues that may warrant further consideration:

- ♦ The need for continued comparisons with other studies of mail and similar systems to strengthen confidence in the accuracy of the findings;
- ♦ More rigorous examination of the alternative approaches for allocation of resource usage and pollutant emissions to mail products; and
- ♦ A review of the scope to determine if some of the elements that are not mail specific should be evaluated separately.

Response of Report Authors to Peer Review Comments

We appreciate the insightful comments and suggestions offered by the peer reviewers, and have evaluated and carefully considered the input provided by each reviewer. In this section, we discuss what we consider the major remaining issues and suggestions raised by peer reviewers, and provide our assessment of the implications for the LCI model and its use moving forward. We begin our discussion with the three general comments stated above and then discuss one additional issue and related peer review suggestions discussed in their attached comments that we believe merits further attention.

There is a need for continued comparisons with other studies of mail and similar systems to strengthen confidence in the accuracy of the preliminary model findings.

We agree that comparing our results with those of other similar or analogous studies, models, and methods can illuminate important issues and also serve to validate our modeling approach, data, assumptions, and to some extent, results. As stated during our meeting with the full peer review panel, we made diligent attempts to identify all studies published in the formal and "grey" literature at the time we prepared the report that are in any way comparable to our analysis, and have included all data that are suitable for comparison in our report. As noted in Section IV, while some of our results track very well with the results from other studies, there are also some discrepancies between our results and those of other investigators. We are confident that we understand (and have articulated) the reasons for some of the observed differences, while for others the causes are not clear. In our view, resolving the root causes of the discrepancies between our results and those of other investigators would likely require direct follow-up with the respective study authors, a step we have not yet taken.

More rigorous examination of the alternative approaches for allocation of resource usage and pollutant emissions to mail class would be appropriate.

As described in Section III of this report, consumption of energy resources and associated pollutant emissions are distributed to classes of mail based upon the share of each of the overall resource usage required to carry out a particular function (e.g., highway transportation). These shares for each mail class and service are tabulated and published by the Postal Service annually.

In response to preliminary feedback from the peer review panel, we modified the model to provide the capability to allocate shares to mail class using three alternative methods: weight, mail volume (number of pieces), and physical volume ("cube") of the product. As discussed above, none of these alternative measures are based upon causal relationships with the resource usage under study. Further, in some instances they provide results that not only differ from our causally grounded allocations, but also from each other. There is no basis in logic or causality for choosing among these three methods. Moreover, our approach [20] already embodies any explanatory power offered by the other alternatives (volume, weight, or cube) and has been rigorously quantified and peer reviewed over a period of years.

Finally, it is unclear that adopting any of the suggested alternative distribution keys would substantially change our results. Viewed from the perspective of total life cycle CO_2 emissions, for example, class-level results change relatively little when one of the alternatives is chosen. For eight of the twelve combinations (four classes times three alternative distribution keys), total emissions change by less than 20 percent, though inordinately large changes(31 to 177 percent) are observed for package services, given its low volume, high weight, and high cube relative to other mail classes.

For these reasons, we do not believe that using any of the suggested alternatives would improve the accuracy or utility of the model, nor do we believe that this issue merits further study or analysis.

The scope of the analysis should be reviewed to determine if some of the elements that are not mail specific should be evaluated separately.

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[20] Our approach reflects important underlying causal characteristics, such as carrier street time for delivery costs, and square footage of buildings for utility usage and costs. These causal characteristics are used by the Postal Service to attribute the appropriate share of resource usage and costs to individual mail Classes.

While acknowledging the importance of the issue, there is considerable value in evaluating the entire mail life cycle in a unified and consistent modeling framework. The Postal Service works in close collaboration with the mailer community, and decisions reached by each party affect the behaviors, environmental performance, and economic success of the other. Moreover, a number of important public policy questions pertaining to the mail have emerged in recent years that make an understanding of the end-to-end energy and emissions profile of the mail stream increasingly important. One cannot approach these questions without having pertinent facts at hand, and the intent behind the model is to contribute some of these facts. In any event, the model structure makes it very simple to pinpoint and extract the Postal Services' "share" of total energy consumption, waste generation, and emissions, so there is no real drawback to considering the upstream and downstream stages of the mail life cycle, other than the limited incremental time and effort required to secure the necessary data and the possible introduction of additional sources of uncertainty.

The analysis would benefit from the inclusion of several additional activities, including internal business travel, employee commuting, and customer drop-off or pick-up of mail at USPS locations, as well as the consideration of capital equipment in the life cycle inventory.

We concur with the suggestion that some of the activities and life cycle stages suggested might be both quantitatively significant and worthy of consideration from a theoretical perspective, particularly internal business travel and customer trips to post offices. The optimal scope of the model and any analysis performed with it depend, however, on the question being addressed. We believe that we have defined the scope correctly to address the question posed in this initial application of the model: the life cycle inventory of four specific mail products. In contrast, if one were interested in determining the inventory for the Postal Service as an organization, then it would be appropriate to at least consider including some of the additional suggested activities.

That said, we do not believe that it is appropriate to include employee commuting and do not believe that it is appropriate to include capital equipment (and its supply chain dimensions). We have performed an initial bounding analysis of the energy and greenhouse gas emissions attributable to USPS employee commuting, and found that they are a significant fraction of the Service's totals for each endpoint. This does not, however, mean that they should be included as part of the life cycle of the mail, for the simple reason that the model is designed to evaluate either *marginal* or *incremental* environmental aspects of postal products. Postal Service employees would commute somewhere else were they not traveling to work at the Service each day. So even in an extreme case in which the employee headcount was reduced significantly in response to a decline in mail flow, the displaced employees would simply commute elsewhere (upon finding new employment), with no net reduction in energy consumed or greenhouse gases emitted. Further, as we understand the application of ISO standards to LCI, practitioners are free to include commuting to work or to exclude it, so long as they clearly describe what they have done.

As far as including capital stock in the LCI model is concerned, it is worthy of note that this is very rarely done, because experience has shown that adding these components generally makes very little difference in the overall results. Calculating such secondary and tertiary aspects adds significantly to the cost of the analysis while contributing very little to its quality.

In cases where such aspects are believed to be important, however, one can use economic input-output models, which have a scope that spans an entire national economy and include the connections among and between all major economic sectors. While the scope of such macro-level models is extremely broad, the level of resolution (accuracy) is very low, so they are most useful in performing bounding analyses. We believe that this type of approach may be of use to us in validating study boundaries, as we discussed in detail during our meeting with the peer review panel, and in estimating the potential magnitude and importance of life cycle stages and activities not explicitly considered in our LCI model. We have performed some limited analysis of this type, and results show that our model captures the most quantitatively important activities related to mail processing and delivery for the endpoints of interest here.

Appendix A
Guide to Postal Product Life Cycle Inventory Model

This Appendix provides additional information describing the Life Cycle Inventory model developed by SLS Consulting, Inc. to evaluate the environmental aspects of U.S. mail products.

The model takes the form of an Excel workbook file, which contains 37 linked worksheets containing background information, assumptions, intermediate calculations, and model results that are organized as follows:

- Six worksheets at the front of the workbook contain detailed LCI results; the tab color for these is white. Two contain results at the functional unit level (one million pieces of mail), two contain results on a per mail mass (kg) basis, and two contain total results. Within each category, results for energy consumption and waste generation and pollutant emissions are provided on separate worksheets.

- One worksheet contains some tabular results illustrating certain issues of particular interest, including carbon dioxide emissions and waste management practices. This worksheet is colored red.

- Next, three worksheets having a black tab color contain, respectively, data required to run the model and assumptions and standard values, and information on the specific mail products being analyzed. Most of the values in these three worksheets are drawn from more basic, detailed data that are provided at the end of the workbook.

- Calculations that characterize the activities, energy consumption, and waste generation and pollutant emissions occurring at each major mail life cycle stage are presented in a series of 14 worksheets that have tabs colored medium blue. These are presented in the order of each stage in the life cycle of a typical mail piece.

- Finally, supporting data and, in some cases, supplementary calculations are provided in a series of 13 worksheets with tabs that are colored orange. The last of these comprises a revision history for recent versions of the model.

The model calculates and presents the following parameters:

- Solid Waste
- Water Pollutant Emissions: Total Dissolved Solids
- Air Pollutant Emissions: Carbon Monoxide, Carbon Dioxide, Hydrocarbons, Nitrogen Oxides, Particulate Matter, and Sulfur Oxides
- Fuels consumed: Diesel, Gasoline, Jet Fuel, Heating Oil, Natural Gas, and Electricity

Waste and pollutants are expressed as kg/million pieces of mail, except on the final summary sheet, where they are expressed in metric tons (MT). Fuels data are generally expressed in the units that are typically used for each one (e.g., kWh for electricity, thousand cubic feet for natural gas, gallons for liquid fuels), though they all are normalized in the summary worksheets to common units (million British Thermal Units (BTUs). Within each sheet, consumption of each fuel is normalized and expressed on the basis of the functional unit (e.g., gallons of diesel fuel per million mail pieces).

Wherever possible, full life cycle impacts of materials and fuels are calculated and summed to provide a complete picture of the scale of the environmental aspects of mail products. So, for example, in computing the aspects from using a gallon of diesel fuel, the model includes both the direct combustion emissions, which are dependent upon the type of engine or device burning the fuel, but also the waste and pollution generated and energy used to *produce* the fuel. In some cases (e.g., electricity generation), these upstream aspects can be of significant magnitude.

A further explanation of each worksheet and its purpose and functions follows.

Results (white tabs)

Sum. of Waste & Emissions-Total provides the highest-level roll-up of the results of the life cycle inventory. This sheet provides, for each mail product and for the four products in total, the waste and pollutant emissions from each life cycle stage and in total. Aspects are summed separately for transportation and manufacturing/facility operation separately, and then summed to provide an overall total for each stage and product. The values in the table are developed by multiplying the calculated waste and emissions per unit found on the third worksheet (Sum. of Waste & Emissions-Unit) by the number of mail pieces (from the Mail Product Definition worksheet).

Summary of Energy Use-Total provides analogous summary information for energy use. Again, results for transportation and manufacturing/facility operation are addressed separately, then summed in the final column (using the common metric of million BTUs). The values in this table are developed by multiplying the energy consumption calculated in the fourth worksheet (Summary of Energy Use-Unit) by the number of mail pieces (from the Mail Product Definition worksheet)

Sum. of Waste & Emissions-Unit provides the calculated waste generation and pollutant emissions from each of 16 defined life cycle stages per million pieces for each product as well as product-level summaries. Waste and emissions for combustion of transportation fuels are calculated separately from those arising from manufacturing and facility operation. The quantities are then summed to create an overall total per unit for each parameter. Individual parameter values are drawn from individual worksheets containing the calculations for each life cycle stage as well as from several worksheets that tabulate and summarize USPS and non-USPS energy use (blue tabs).

Summary of Energy Use-Unit summarizes the fuel consumed by type for both transportation and manufacturing/facility operation for each of nine life cycle stages for each of the four mail products. (Note that some of the 16 stages comprising the analysis of waste generation and pollutant emissions consume little or an indeterminate amount of energy; these have been consolidated into the nine stages listed in this worksheet.) Fuels data are then combined using a common metric (MM BTUs/million pieces) to put all results in a consistent and comparable basis. Parameter values are drawn from individual worksheets containing the calculations for each life cycle stage as well as from several worksheets that tabulate and summarize USPS and non-USPS energy use (blue tabs).

Model Assumptions and User Input (black tabs)

Assumptions & Standard Values lists an array of data that are required to perform the calculations in the model. These data fall into one of three basic categories. The first is ***user-specified values*** (shaded aqua). At present, we have populated the model with our best estimates of the actual values of these variables, though these can easily be changed to accommodate more recent/accurate data. For some variables, it is expected that the values within a range will sum to 100 percent. When this occurs, the cell in which "100%" appears will be shaded green. The second category is ***constants***, which have been drawn from published sources, as noted on this worksheet. The third category is cells containing ***values that are drawn from more detailed data*** presented at the end of the workbook. Many of these data pertain to vehicle capacities, fuel mileage, and the like.

Mail Product Definition and **Mail Product Composition** provide information on the specific mail products that will be analyzed using the LCI model. The former draws product volume, weight, density, and other characteristics from the data worksheet "Mail Product Characteristics" and requires user input on the percentage of non-paper product content, and several parameters that are used in downstream steps to analyze printing intensity and aspects. Similarly, Mail Product Composition requires the user to specify, at a general level, the percentage composition of each mail product, and then computes the weight of each major component, both paper/board and otherwise.

Model Calculations (blue tabs)

Impact of Contained Material then takes these user inputs and computes the air and water pollutant emissions and energy consumed for each material in each mail product and in total. These results are drawn to and comprise the middle of the first row of the "Sum. of Waste & Emissions-Unit" sheet at the beginning of the workbook.

Mail Proc & Prep-Printing and **Printing emissions&consumption** quantify the energy and emissions associated with printing each mail product and preparing it for entry into the Postal system. The latter retrieves user-specified information from the "Mail Product Definition" and computes the quantities of energy consumed and pollutants emitted on the basis of one million images, while the former normalizes these results by the number of printed sheets per mail piece.

USPS -- Packaging & Processing provides opportunity for user input for each mail product being analyzed with respect to quantities of packaging material used and recycled, and the percentage of each product that is undeliverable as addressed (UAA). The worksheet then calculates the quantities of packaging material and UAA mail that enter the waste management process.

USPS Mail Product Energy Use computes the product-level energy used to transport and deliver each mail product and provide the processing energy required to ensure that it is routed and shipped appropriately within the Postal system. Computations are performed by using the Service's data on fuel used for facility operation and each transport mode, found in sheet "USPS Fuel Use," and distributing each product's share of the total fuel consumed according to fuel/mode-specific distribution percentages, which are found in sheet "USPS Distribution Keys." Product-level consumption is normalized by dividing the results by the number of pieces (in millions) of each mail product. These data are drawn from the "Mail Product Definition" sheet.

Mail Recipient Use computes the total and material-specific disposal and recovery rates for each mail product following use by the mail recipient, using product-specific retention rates that are entered by the model user. Materials to be recovered are quantified, and these quantities then serve as inputs in the "Collection & Material Recovery" sheet to calculate the quantities of each material recovered for each product. The remaining materials quantities serve as inputs to the "Residual Disposal-WtE" and "Residual Disposal-Landfill" sheets, with the relative portions reporting to each defined by the percentages indicated on the "Assumptions & Standard Values" sheet. These percentages currently are based upon national averages, but can be modified by the model user.

Collection & Material Recovery takes the quantities of material calculated in previous sheets addressing material recycled both by mail recipients and the Postal Service, and calculates the quantities of basic recovered commodities (paper, paper board, plastics). It then computes the quantities recovered using the recovery percentages specified on the "Assumptions & Standard Values" sheet (which again can be modified by the user), with the residual material going to disposal. The energy use and pollutant emissions associated with carrying out these activities also are computed on this sheet. Recovered materials are assumed to be shipped to a buyer located at a distance specified in the "Assumptions & Standard Values" sheet, at which point they depart from the analysis.

Residual Disposal-WtE takes the quantities of material calculated in previous sheets addressing material recycled both by mail recipients and the Postal Service, and calculates the energy, in various forms, required to manage this material as well as the energy generated through waste combustion. Pollutant emissions associated with this energy use also are calculated. Ash quantities are computed based upon the ash content specified on the "Assumptions & Standard Values" sheet, which then report to the "Residual Disposal-Landfill" sheet.

Residual Disposal-Landfill aggregates the quantities of material calculated in the previous life cycle stages that are not recovered and calculates the energy, in various forms, required to manage this material and related pollutant emissions. Also, given the importance of methane as a greenhouse gas, landfill gas emissions (expressed in CO2-equivalents) are computed for each product, based upon material-specific rates provided in the "Assumptions & Standard Values" sheet.

USPS Facil. Energy & Emissions takes the mail product-level consumption of fuel oil, natural gas, and electricity in Postal Service facilities computed in sheet "USPS Mail Product Energy Use" and computes the life cycle waste, pollutant emissions, and precombustion energy associated with each fuel in facility end uses. Unit emission factors are provided in sheet "Fuel Life Cycle Emissions."

USPS Transport Fuel &Emissions takes the mail product-specific quantities of fuel calculated in sheet "USPS Mail Product Energy Use" and applies a series of emission factors that are specific to the vehicle type and size being used to perform particular Postal Service functions to compute emissions of indicator pollutants. Direct emissions are calculated for each fuel/vehicle type combination for each product, then precombustion emissions (those from producing the fuels) are calculated by applying emission factors drawn from the sheet "Fuel Life Cycle Emissions." The two sets of emissions are then combined to arrive at totals for each fuel/vehicle type within each mail product. Below these calculations, a similar set of calculations is performed that computes the life cycle waste and emissions from fuel use at Postal Service facilities that process and transport the mail, except that both direct and upstream waste and pollutant emissions are captured in one set of calculations. Precombustion energy use also is computed for both facility and transportation energy use, and is included in the totals provided on the "Summary" sheets.

USPS Institutional estimates direct, precombustion, and total waste generation, pollutant emissions, and precombustion energy consumed for the motor vehicle fuels and facility energy used by the Postal Service that are not distributed to individual mail products or services.

Non-USPS Transport Emissions takes a similar approach, by first calculating the fuel used to transport mail or its upstream or downstream components between life cycle stages, then computing the direct and indirect waste and emissions associated with this fuel use. Fuel used is calculated based upon the quantity of each material transported, and the assumed distances between each origin and destination, type of transport equipment, and capacity of that equipment as specified in the "Assumptions & Standard Values" sheet. Precombustion energy use in producing the transportation fuels also is computed, and is included in the totals provided on the "Summary" sheets.

Waste Mgt Equip Emissions provides calculated pollutant emissions (air pollutants only) from operating the heavy equipment needed to process material at waste management facilities. It includes operating scenarios for each of the mail products examined here, based upon material volume. Heavy equipment is specified for an appropriately sized material recovery facility (MRF), waste-to-energy facility, and landfill for each product. Fuel consumption is calculated for each piece of equipment based upon the assumed daily capacity and operating time (hours/day) for the waste management unit in which it operates and multiplied by the quantities of the material in question. The fuel consumption rate is used to compute pollutant emissions based upon the type and size of the engine in each piece of equipment, and are expressed as kg/million pieces of mail. The emissions for each mail product are the sums of the waste and emissions from each piece of equipment used to manage that material at a particular life cycle stage. These results are then drawn and incorporated into the totals provided in the sheets addressing the appropriate life cycle stages ("Collection & Material Recovery," "Residual Disposal-WtE," and "Residual Disposal-Landfill").

Supporting Data (orange tabs)

Mail Characteristics provides data on the mail products that are the focus of this model. Separate tables on this sheet provide volumes, weights, and other physical data as well as information on delivery points. The basic mail characteristics data are drawn into the "Mail Product Definition" sheet, which then drives the downstream calculations in the model.

USPS Distribution Keys provides data from relevant Postal Service cost segments and components analysis. The cost percentages within specific segments and components are used to distribute Postal Service fuel use appropriately to each mail product in the analysis, as well as to the remaining mail products and services not explicitly considered in the model and institutional (network) operations. Within each segment and component, the Postal Service has established the cost that is attributable to each mail product, to services, and to general (institutional) operations. The percentage of the total cost within each cost segment/component that is attributable to each mail product is computed at the bottom of this sheet, and these percentages are used to distribute the fuel used to each product. Different distribution keys are used to address different functions and activities, so each fuel type/use may have its own distribution key.

Raw Material LCI Data provides the data used to compute the waste and emissions associated with the paper, board, and other materials used to create the mail. These calculations are made in sheet "Impact of Contained Material."

USPS Fuel Use provides the most recent information on national Postal Service fuel use by fuel type and application. These data are used to calculate the fuel expended to transport and deliver each mail product.

2006 USPS Vehicles Data provides background information on the Postal Service fleet, including fuel economy data that are drawn into the "Assumptions & Standard Values" sheet.

USPS Vehicle Characteristics provides information on the types and capacities of Postal Service Vehicles that are drawn into the "Assumptions & Standard Values" sheet.

Transport Emission Factors provides data on fuel economy and air pollutant emissions associated with operating various engine types and sizes in different transport applications, including highway, rail, and air. These data are drawn into various other sheets to calculate pollutant emissions and/or vehicle miles traveled.

Fuel Life Cycle Emissions provides information on the precombustion and full life cycle waste and emissions associated with producing different types of fuel (e.g., diesel, natural gas) and employing them in various end use applications (industrial boilers, industrial equipment). These data are used to compute the waste and emissions from fuel use at Postal Service facilities and from transport of mail and its components throughout the mail life cycle.

EPA Printing Data provides emission factors for flexographic printing. These factors are used to compute printing emissions in sheet "**Printing emissions&consumption."** Accordingly, the model reflects the implicit assumption that flexographic printing emissions are representative of those of all major printing types used to produce the mail.

Waste Mgt Equipment provides background data on the heavy equipment used to manage residual materials at landfills, MRFs, and similar facilities. This information was employed to develop the scenarios reflected in the sheet "Waste Mgt Equip Emissions."

Nonroad Emission Factors provides air pollutant emission factors for heavy duty diesel engines used in nonroad applications. These factors are drawn into and used in sheet "Waste Mgt Equip Emissions" to calculate equipment- and mail product-specific air pollutant emissions.

US Power Plants provides national level estimates of the average unit air pollutants emitted per unit of electricity generated. These data are incorporated into sheet "Fuel Life Cycle Emissions" and used in other sheets to compute the air pollutant emissions associated with electricity use.

Revisions provides a revision history showing the significant changes made to refine the model during the past several months.

Appendix B
Final Peer Reviewer Comments

Peer Review Report
The Environmental Impacts of the U.S. Mail:
Initial Life Cycle Inventory Model and Analysis

Submitted by:
Michael T. Huguenin
Industrial Economics, Incorporated
Cambridge, Massachusetts

Introduction

Thank you for the opportunity to review and comment on the documents entitled *The Environmental Impacts of the Mail: Initial Life Cycle Inventory Model and Analysis*, prepared for the U.S. Postal Service (USPS) by Booz-Allen Hamilton, Inc. and SLS Consultants, Inc. and dated February and April 2008. As part of my review I examined these documents as well as the associated Excel workbooks containing 34 and later 37 worksheets. For convenience, in the paragraphs below I refer to the subject documents and Excel workbooks together as the "Study." In addition, as part of my review I consulted several additional documents including peer-reviewed literature as well as government reports; and I met with the study's authors, the USPS sponsors, and two other peer reviewers in Washington, D.C. on April 7, 2008. Additional documents relevant to my comments are cited in the bibliography at the end of this document.

The Study presents a life-cycle inventory (LCI) model and analysis of the U.S. mail stream and examines energy consumption, waste generation, and release of several pollutants caused by the creation, distribution and ultimate disposal of the mail. Design and conduct of LCI studies are difficult for both theoretical and practical reasons, but for the most part the Study's authors have done a commendable job solving a variety of study design and data acquisition challenges. I found the written reports and Excel worksheets particularly concise and clear, which enables one to gain a thorough understanding of exactly how the study was conducted. Overall, this is a strong study which should reflect well on the authors as well as their U.S. Postal Service sponsors.

In the comments below I outline several issues that I believe merit consideration. The text below is organized in three additional sections: (2) Overarching Concerns, (3) Specific Issues and (4) Bibliography. Note that in sections (2) and (3) I provide answers to the five Questions for Peer Reviewers set forth on page 21 of the February 2008 Study document.

Overarching Concerns

I have two overarching concerns. First, more work is needed to assess the **validity or accuracy** of the LCI model and analysis**.** Second, the Study includes limited discussion or quantitative treatment of either **variability or uncertainty**.

Validity/Accuracy: The validity or accuracy of LCI results often is very difficult to evaluate. LCI by its nature generates results that do not easily compare with available statistics and other measures (both private and public), and independent methods rarely exist to develop similar findings. Thus, LCI authors and reviewers often are limited to evaluating the *plausibility* of an LCI application. While plausibility is important, it alone does not provide much comfort that the numbers generated by a LCI study actually are correct. I find the results of the Study quite plausible but remain unconvinced about whether they actually are "right."[21]

The authors provide comparisons of the Study results with a variety of statistics on pages 21 through 26 of the April draft report. While I find the comparisons interesting, and they provide evidence for the plausibility of the Study results, they do not build a strong case for the accuracy of the Study for two reasons. First, I don't know how to establish strong priors on what most comparisons should show for the Study to be judged accurate. For example, do the four classes of mail *actually* contribute 0.47 percent of national CO_2-equivalent emissions, as reported on page 22 of the April draft Study? How does one evaluate the accuracy rather than just the plausibility of this and similar comparisons?[22] Second, how does one select the comparisons to report in the first place? While I suspect the Study authors developed comparisons wherever they could find relevant statistics, the lack of some principled basis for selecting comparisons might create the impression that only comparisons judged favorable or plausible are reported.

I also am puzzled by the authors' use of results for the four major mail classes, rather than the mail stream as a whole, in many of these comparisons. For example, at the bottom of page 21 in the April draft the authors compare 632 trillion BTU consumed by the four major mail classes with total US manufacturing energy use (22,666 trillion BTU) and with energy use in several manufacturing sectors such as petroleum refining, chemicals and primary metals. Exhibit 10 reveals that total mail stream energy consumption is about 726 trillion BTU, computed by adding energy consumption for other mail products, special services and USPS institutional to the subtotal for the four major mail classes. This figure is about 15 percent larger than the 632 trillion BTU consumed by the four major mail classes, and in my view is the more relevant comparison with the national and other industry totals.

Similarly, Exhibit 9 reveals that total mail stream CO_2-equivalents equal about 39.4 million MT (again computed by adding CO_2-equivalents for other mail products, special services and USPS institutional to the subtotal for the four major mail classes), an 18 percent increase over the 33.3 million MT reported for the four major mail classes. In my view this larger figure is more relevant to compare with estimates of CO_2-equivalents generated by other sectors.[23]

LCI practitioners often assess validity in part by comparing results to other LCI studies that consider the system under study in part or whole. Thus I found the comparisons of some Study results with the UPS corporate sustainability report and the Heinz Center magazine study to be potentially the most relevant evidence of validity offered in the Study.[24] However, both UPS and the Heinz Center apparently report estimates that are substantially different from the Study. While the Study authors offer explanations for

[21] The numerical accuracy of results generated by large, data-intensive models also is a concern. Speaking from my own experience, it is surprisingly easy for calculation errors to creep into large spreadsheet models and go undetected. I suggest the Study authors add an explanation of the QA and error checking protocols implemented to assure numerical accuracy within the Excel workbook.

[22] I note that the authors make the same argument of plausibility even though the percent of national CO_2-equivalent emissions attributed to the four major mail classes jumped from 0.19 percent to 0.47 percent between the February and April drafts of the Study. Apparently both figures are deemed plausible despite the April estimate being 2.5 times greater than the February estimate.

[23] I note also that some numbers cited in the discussion of comparisons on pages 21 to 26 cannot be generated from or found in the exhibits in the report. While these numbers can be found in the Excel worksheets or the referenced sources, the reader's task would be eased if all numbers used in these comparisons were placed in the report exhibits.

[24] These comparisons are found on pages 25 and 26 of the April 2008 Study report.

these differences, these explanations are not supported by detailed analyses on a process- or unit-emissions level.[25] More work should be done to understand the detailed reasons for these differences.

I understand that evaluating validity and accuracy of LCI models is a very difficult undertaking. I commend the authors for providing the comparisons included in the report. But in my view more should be done. In particular, I suggest further comparison of the Study's results to other LCI studies of postal systems, or service organizations, distribution systems or other processes with similar characteristics to stages within the overall mail system.

I conducted a brief internet-based literature search and located four additional LCI papers in the peer-reviewed or gray literature that might provide relevant comparisons with the Study.[26] Several involve LCI analyses of service or distribution systems that might have similar characteristics, at least in part, with the U.S. mail stream (e.g. Junnila 2006, Norris *et al.* 2003, Rosenblum *et al.* 2000). One paper appears particularly relevant – a working paper by researchers at Carnegie-Mellon University prepared in March 2007 that reports a LCI of operations conducted by the U.S. Postal Service (Mangmeechai and Matthews 2007, hereafter referred to as M&M 2007).

Table 1 below provides a comparison of some results from the Study versus M&M 2007.

Table 1
Comparison of Selected Results
USPS Study versus Mangmeechai and Matthews 2007

	USPS Operations Only		**Overall Mail System**	
	USPS Study	**M&M 2007**	**USPS Study**	**M&M 2007**
Trillion BTUs	176	41	726	~205
Source within study:	Exhibit 10	Figure 5	Exhibit 10	Page 13, line 22
Million MT CO_2	10.9	4.8	39.4	12.7
Source within study:	Exhibit 9	Figure 5	Exhibit 9	Page 13, line 21

Table 1 shows that M&M 2007 estimate significantly less energy consumption and CO_2-equivalent releases than the Study, both for USPS operations only and for the overall mail system. Energy consumption estimated by M&M 2007 is 23 to 28 percent of that estimated in the Study, while CO_2-equivalent releases estimated by M&M 2007 are 32 to 44 percent of that estimated in the Study. I note that the M&M 2007 estimates for USPS operations are for base year 2005 and for the overall mail system are for base year 1997, compared to the USPS Study base year of 2006, but these differences in timing are unlikely to explain the differences in results between the two studies.

I do not fully understand the methods, data and results reported by M&M 2007 and I have no reason to believe that their results are more accurate or reliable than the Study. Still, in my view it would be worthwhile to conduct a detailed comparison of the Study with the results reported by M&M 2007 to see what might be learned.

More generally, additional comparisons with LCI studies that are in part comparable with the Study would generate a better understanding of the energy and environmental impacts of the U.S. mail stream,

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[25] The Study authors compare the UPS and Study figures on a per-dollar of revenue basis, but offer no rationale for why this revenue adjustment is appropriate. I do not understand the logic of this comparison.

[26] The Study authors may have reviewed these papers, as well as other relevant literature not cited in the Study report. It would be useful to provide a complete bibliography to document all literature reviewed in preparing the Study.

as well as building the case for the accuracy of the Study's findings. In my view much of the insight gained from LCI studies comes from the thought process of constructing the study and then comparing the study's results with relevant findings by other authors, rather than from the specific numbers produced by any single study. [27]

Variability/Uncertainty: The Study report and Excel workbook clearly indicate that (a) many variable parameters are incorporated using averages or "representative" figures (e.g. parcel weights, freight aircraft characteristics) and (b) many parameters are uncertain. The April draft of the Study includes a discussion of variability and uncertainty on pages 12 and 13, and presents a sensitivity analysis of alternative allocation keys on pages 17 and 18. These sections are useful but in my view more should be done, particularly to explore uncertainty in the Study results.

The authors argue on page 13 of the April draft that the Study results "are accurate within a range that is typical of policy models, i.e., a factor of 50 to 100 percent." However, there is no basis provided for the estimated range of 50 to 100 percent. Monte Carlo and related methods can be used to explore the quantitative ramifications of uncertainty, and simple software is available to apply these methods within Excel spreadsheets.

In my view it would be useful to conduct some focused Monte Carlo or other analyses that identify (1) model input parameters that have the greatest impact (per unit) on model results, (2) the range and central tendency for these input parameters, and (3) the uncertainty in model results caused by varying the important input parameters through their likely ranges. This uncertainty analysis would provide the authors with a reasoned, quantitative basis to set forth an overall accuracy range for the Study's results. It also would allow discussion of whether uncertainty differs among study outputs, for example for energy consumption versus various waste and emission estimates.

Specific Issues

I have thoughts about the Study in three additional areas.

System Boundary[28]: The boundaries of the postal system under consideration, including the upstream stages involved in mail creation and the downstream mail recycling and disposal stages, are clearly described in the Study and make logical sense to me. However, my brief review of other LCI literature, particularly Junnila 2006, suggests that several stages not included in the Study but included in other LCI analyses of service operations might be important. These include supply chain stages that provide capital equipment to the postal service (e.g. vehicles, equipment, perhaps buildings), USPS worker commuting activities, and business-related travel by USPS staff. Given the large magnitude of the USPS physical plant and workforce, inclusion of these stages might be important to accurately reflect the environmental footprint of the mail system. In addition, these stages can be directly influenced by USPS policies to the extent they are shown to be important.

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[27] The discussion in the preceding paragraphs also provides my answers to the first, fourth and fifth questions posed to peer reviewers on page 21 of the February draft of the Study. M&M 2007 is the only other LCI model of the postal system known to me. I suggest further literature review, and in particular comparisons with other relevant LCI studies, as the best approach to improving the accuracy of the LCI model, determining which model components are most in need of further improvement, and locating additional sources of relevant data.

[28] This section provides my thoughts on the second question posed to peer reviewers on page 21of the February 2008 Study draft.

The Study's authors discuss several system boundary issues on pages 19 through 21 of the April draft. This section provides a strong, data-based argument that neglecting the life cycle stage of tree growth prior to the pulp and paper stage does not significantly affect Study's results. The authors also acknowledge the possible importance of capital equipment, the USPS worker commuting, and travel by USPS customers to pick up mail. I suggest the Study's authors conduct further quantitative analyses (as done for tree growth) to provide a stronger basis for excluding or including other stages that might be important.[29]

Environmental Endpoints[30]: Environmental endpoints highlighted in the Study include solid waste, dissolved solids, hydrocarbons, particulate matter, and CO_2-equivalents. In my view solid waste and CO_2-equivalents are useful and meaningful to report. The other highlighted pollutants are less meaningful, in part because they are only a subset of all water and air pollutants and in part because the importance of these releases depends on *where* the release occurs.

I note that the Excel worksheets include estimates for a number of other pollutants for some processes (e.g. NO_x, SO_x, mercury, chlorine, phosphates, nitrogen, ammonia), and I understand the authors generally included all pollutants with available data in the worksheets. I am not sure how the authors decided on the specific pollutants to highlight (although these choices make sense to me). I suggest the authors add a discussion of data completeness for environmental endpoints that sets out, perhaps in tabular form, the availability of pollution data for each LCI stage included in the study. This discussion should state for each stage whether pollution generation data exist and for which pollutants, and where no data exist whether we expect actual generation to be insignificant or zero, versus unknown. This discussion would build confidence in the completeness of data for the environmental endpoints considered.

Presumably the specific environmental endpoints highlighted in the Study document are those with relatively complete data throughout the mail stream system. When research tradeoffs must be made, I favor developing more complete data (that is, for all system stages) on a shorter list of endpoints rather than proceeding with less complete data for a larger number of endpoints.

If the authors continue to highlight emissions of pollutants such as particulate matter or dissolved solids where the location and conditions of release have a strong bearing on the potential for human and environmental harm, I suggest that an attempt be made to characterize the conditions of the release location. For example, the Study's usefulness for air pollutants would be increased by classifying releases by the characteristics of the receiving air shed (e.g. non-attainment areas) based on knowledge of where USPS as well as upstream and downstream facilities are located. It also would be useful to set out $PM_{2.5}$ separately from PM_{10} because these substances have different human toxicology.[31]

Other Mail Products, Special Services, and USPS Institutional: The Study emphasizes results for four "major" mail products: first-class mail, standard mail, periodicals, and package services. Results for two

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[29] I note that the Mangmeechai and Matthews 2007 study discussed above, by using an economic input-output model (EIO-LCA), presumably includes capital equipment and business-related travel by USPS staff in their reported "Total USPS" results.

[30] This section provides my thoughts on the third question posed to peer reviewers on page 21of the February 2008 Study draft.

[31] The same might be done for dissolved solids and other water pollutants, but I question the value of doing so unless the specific water pollutants analyzed are toxic to humans or ecosystems in the receiving waters being impacted. Obviously this would be difficult to ascertain given the many locations of discharges from the mail stream system under consideration.

additional products (other mail products and special services) are reported in less detail.[32] The volume of other mail products is similar to that of package services, and one interesting result of the Study is that other mail products generate a significant portion of transportation energy consumption and CO_2-equivalents. To enhance clarity and consistency, I suggest that other mail products be evaluated in the same manner as the four "major" mail classes (i.e. include a full upstream and downstream analysis), and Study results be reported for five product classes rather than four product classes. As a result a table such as Exhibit 9 would report other mail products above the Subtotal line.

I also am puzzled by the lack of discussion of USPS institutional energy consumption and waste/emissions. While I understand that institutional energy consumption and waste/emissions are considered "fixed" with regard to mail volume, they are real by-products of the overall system set up to handle the mail stream. In discussing the Study's results I suggest more emphasis on the total figures for the overall mail stream system.

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[32] Other mail products include Express and Priority Mail, while special services include products such as Registered Mail, Certified Mail, money orders, COD services and similar.

Peer Review Report
The Environmental Impacts of the U.S. Mail:
Initial Life Cycle Inventory Model and Analysis

SUBMITTED BY:

Edwin Pinero
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Golisano Institute of Sustainability
Rochester Institute of Technology

Summary and General Comments:

RIT was asked to review the LCI study provided by the United States Postal Service. Edwin Pinero was the primary reviewer. In addition to specific responses to the proposed reviewer questions, which also include specific comments, we offer the following general observations:

- The report does clearly explain the scope and limitations of the study, and readily acknowledges that there are many areas that would benefit from further work.
- The question of when mail becomes mail, and to what extent attributes are unique to mail as compared to simply the item, needs to be resolved. In other words, the life cycle elements included herein regarding the impacts of the manufacture of the piece of mail may not be representative of mail. USPS provides a service- that is; they deliver items from one entity to another. The life cycle implications of the item's manufacture are such that they would not necessarily change whether or not the USPS adjusted its processes. The same applies for end user impacts. Without the USPS, a magazine would still get published, be bought, read, and discarded. Although it is true that how the magazine is distributed, how many are made, and how many are bought would be affected by USPS decisions, including the piece of mail's inherent attributes in the mail assessment may be misleading. This issue is different for items created specifically to be mailed (advertising flyers, etc). There needs to be a way to distinguish these two types. This issue will become important when the LCI is used to make decisions, because the USPS may discover that they have less of an effect on the overall impacts than hoped.
- It may be more prudent to limit the scope of the LCI from when the piece enters the USPS system until it is delivered. This will facilitate future discussions when one compares mail to other methods of getting the information (internet, telephone, etc.). This approach may reduce the analytical effort, especially since the values would be the same regardless of what USPS did with the mail.
- There are many opportunities to do sensitivity analyses. Where inputs have high variability in values, but data are limited, a sensitivity test may be prudent to assess how important that unknown really is. See specific comments below.
- Some factors not considered may be important. For example, the size of the USPS workforce and the related employee commuting implications may be a key factor in deciding how to address the life cycle implications of mail. See below for more specific examples of other parameters worthy of consideration.
- Recognizing this is a preliminary LCI and not intended to be a full assessment with recommendations, it is not clear exactly how some of the information will be used. Is the intent to try to influence item attributes through how the USPS will handle it?

Responses to Questions

To your knowledge, is this model unique or do you know of other models/studies that examine the full life cycle inventory of the mail? Are there previous efforts that address particular mail products or portions of the life cycle? Please identify and describe any such studies or models.
There was a study done by the USPS within the past two years evaluating the life cycle implications of advertising mail vs. other methods of getting advertising information. However the status and ultimate purpose of that study is not known to the reviewer.

The model appears unique in that it does not use a commercially available LCA tool. Having said that, straightforward calculations of life cycle impacts using published equations and methods is not unique. Not using a model and instead using a straightforward excel spreadsheet with published conversions has value in terms of transparency and ease. A disadvantage however is that it may not benefit from peer reviewed databases that have actually calculated LCI data for various items. Secondly, formal models have weighting factors and sensitivity corrections. General conformance to the ISO standards introduces a high level of confidence and transparency in the LCI process.

The report makes reference to a study done by UPS. We would caution using studies from UPS, FedEx, etc because the nature of their delivery system and related business drivers may be such that comparisons are inappropriate. For example, relative use of aircraft and aircraft size and range of travel may differ between these organization types.

Based upon your knowledge and experience in applying life cycle inventory concepts, do you believe that in constructing the model, we have omitted any life cycle stages or activities that are likely to be important? If so, what are they and what underlies your belief that they are important given the defined scope and boundaries of this study?
As stated in the summary, we contend that there may be elements included that may not need to be because they are not unique to the fact that the piece is mail. On the other hand some mail-specific issues are not considered. For example, the fact that mail trucks are not driven like other vehicles implies general fuel economy conversions may not be appropriate. Mail trucks tend to do much stop and go driving. Second, the nature of mail operations influences the number of employees, work hours, etc. which have commuting and other related impacts. For example, centralizing mail operations means more commuters in small areas. Third, because so much emphasis is put on landfilling for solid waste, not much is said about land use implications. Landfill-related attributes are listed in Exhibit 2, but do not include land use impacts, such as biodiversity effects. However, because more mail is recycled than probably implied by this report, the landfill element may be less than predicted. Finally, is business mail handled differently than residential mail?

Do you believe that the model incorporates consideration of an appropriate set of endpoints (environmental aspects) given its intended purpose? If not, what constituents or other endpoints would you add, delete, or modify? If you recommend adding constituents, what sources would supply the necessary inventory data?
If anything, it has too broad a scope, and includes endpoints outside the realm of when an item becomes, or ceases to be, mail. As to data to infill the missing elements of the mail phase (see comments elsewhere in this report), much information may be obtained from the USPS reporting to the various executive orders. This source of information is specific and relatively current to the USPS.

What specific techniques, if any, would you recommend to improve the accuracy of the quantitative estimates of environmental aspects computed by the model? In your judgment, which model components are most well-developed and complete and which are most in need of further development?

The results confirm what one would expect intuitively; that being the fact that environmental impacts vary more by mail type and not by how the USPS handles it. Secondly, the results show that the bulk of the USPS impact related to mail is in transportation, which makes sense considering that the USPS provides a service of mainly moving mail from one entity to another.

First and foremost would be sensitivity analyses for attributes that the data show as having wide ranges of values and situations where data are scarce and questionable. This will help define whether that questionable or missing information is worth pursuing. Second, would be including some of the USPS operation specific attributes, such as employee impacts, etc. Third, it may be useful to further explore the distinction between mail and its packaging. Whereas the USPS may not be able to influence product-specific attributes, it may be able to influence how it is packaged. Fourth, and as stated in the report itself on project limitations, the printing phase impacts will need to draw on additional data source because there are now so many methods and techniques. Also, significant work has been done by the printing industry on life cycle implications of printing methods.

It would be interesting to explore the impact of how the pieces of mail, or more so, the information contained within, would get from point A to point B without the USPS. This would tell us more about the environmental impact of mail. For example, knowing that 79% of energy is consumed in the paper manufacturing process doesn't attest to the impact of mail. Otherwise, as written, one can imply that the USPS is a cause of this energy use. Again, drilling deeper to distinguish between items that have another purpose and are simply delivered by the USPS vs. items created specifically to be mailed would help fine tune the results.

What additional sources of life cycle inventory or other data do you know of that could be drawn upon to supplement our existing information base? How can the data they contain be used most productively to improve our model?

For USPS-specific operations, reporting information for executive orders and other greening of the government requirements is one source. The USPS has a long history of being a leader in striving for sustainability through implementation of various greening activities. Second, databases provided as part of commercial LCA tools may offer value. Third, EPA may have data on recycling rates of mail or related types of wastes. Finally, because mail is predominantly paper, the forestry and natural resource elements should be further explored. Forestry certification efforts and trade associations may have specific data on aspects and impacts associated with this life cycle stage. This information could be used to assess biodiversity and land use impacts, as well as carbon sequestration potential.

The databases and conversions used are well-documented and come from credible sources (EPA, DOE, etc). We would only caution the currency of information and actual scope of the results. For example, as we commented above, the printing impacts database may be quite limited relative to the actual variations available in today's market.

Conclusion

The report does an admirable job of characterizing the solid waste, air and energy impacts of mail. It also is clear as the limitations and scope used. Finally, it clearly identifies future work and areas needing enhancement. With that in mind, we conclude that the next iteration should:

- Integrate aspects unique to USPS operations (such as truck use)
- Include more USPS-specific aspect (employees, etc)
- Include more sensitivity analyses to document how much of a concern the variable or missing data really is

- Narrow the scope to not include issues that are not mail-specific (the issue of when does “mail become mail?”)

Expanded Comments Following Review of the Revised Report

The revised report fairly addresses the points raised in the Peer Review (especially the forestry and end of life management issues, among others). There are adequate explanations to explain the rationale behind decisions, especially in those cases where decisions may have diverged from a peer reviewer’s comment. Specifically,

- The section on Allocation of Common Mail Processing Inputs and Outputs does an excellent job of explaining the volume-variable issue;
- The explanations of deviations from the ISO standards are now very clear;
- The expanded section on variability and uncertainty is addresses the concerns which were raised at the peer review meeting; and
- There is excellent discussion of the end of life issue and sensitivities.

Peer Review Report
The Environmental Impacts of the U.S. Mail:
Initial Life Cycle Inventory Model and Analysis

SUBMITTED BY:
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Thank you for the opportunity to re-review “The Environmental Impacts of the Mail.” These comments are based on the April 2008 revised version.

Response to Review Questions

To your knowledge, is this model unique or do you know of other models/studies that examine the full life cycle inventory of the mail? Are there previous efforts that address particular mail products or portions of the life cycle? Please identify and describe any such studies or models.
I don’t know of other mail LCAs.

Based upon your knowledge and experience in applying life cycle inventory concepts, do you believe that in constructing the model, we have omitted any life cycle stages or activities that are likely to be important? If so, what are they and what underlies your belief that they are important given the defined scope and boundaries of this study?
Yes. The revised version addresses the implications of growing trees, but this analysis needs to be significantly revised to correctly approximate the net carbon emissions.

Do you believe that the model incorporates consideration of an appropriate set of endpoints (environmental aspects) given its intended purpose? If not, what constituents or other endpoints would you add, delete, or modify? If you recommend adding constituents, what sources would supply the necessary inventory data?
The endpoints are fine for this purpose.

What specific techniques, if any, would you recommend to improve the accuracy of the quantitative estimates of environmental aspects computed by the model? In your judgment, which model components are most well-developed and complete and which are most in need of further development?
The allocation of environmental impacts based on volume variable costs has been expanded to include allocation based on weight, physical volume, and per item. The analysis would be improved if each of these allocations were presented on an even basis, letting the results speak for themselves and explaining why different allocations produce different results. Changing the allocations does significantly change the results. These changes should be explained; that will help readers understand the basis of the calculations and the reason that different results follow from different assumptions.

The presentation of energy use is unclear. Exhibit 10 is titled “Energy Consumption – Total” but it only shows a third of the total energy use.

The discussion of the effects of growing trees does not appear to be correct. The calculations associated with Exhibits 14 and 15 should be revised, or clarified.

Detailed Comments

ES-2: The text says: "Total energy consumed by the four mail products accounts for 0.6% of national energy consumption, a figure that seems reasonable given the quantities of mail in the U.S. economy, and the energy-intensive nature of paper and board production, printing, and motor vehicle transportation." This is not consistent with Exhibit 10. Total US energy consumption is approximately 100 quads. Exhibit 10 shows total energy use as 176 trillion quads. That comes to 0.176/100 or approximately 0.2%, not 0.6%. On page 21 the text says that the total lifecycle energy use is 632 trillion quads. ~~Apparenlty~~Apparently, although Exhibit 10 is titled "Energy Consumption – Total", it is actually showing only a third of the total energy consumption.

Framework (p. 3): Nice elaboration of how the method differs from ISO standards.

Model Structure (p. 6): Nice addition of two additional worksheets in the Excel model to show results on a per kilogram basis. I have not seen these worksheets or the revised model, so I cannot evaluate the changes in the model.

p. 8. Allocation of Common Mail Processing Inputs and Outputs
The inclusion of alternative allocation methods is a significant improvement upon the first draft. However, the discussion provides the impression of bias toward the allocation method used originally. The arguments in favor of the variable cost allocation are weak or at least not easy to understand and not supported by evidence. The text would be improved if the different allocations were explained on ~~a~~an even-handed basis. For example, rather than the current text:

("To accomplish this distribution by product, we have used a relatively simple but rigorous "top down" approach in which we allocate shares of resource usage and pollutant emissions to mail products based upon each product's share of the resource usage that creates these missions. These shares for each mail product and service are tabulated and published by the Postal Service annually, and are organized by cost segment and component. The model also provides the capability to allocate the shares to mail products using three alternative methods: the weight, mail volume (number of pieces), or physical volume ("cube") of the product. None of these alternative measures are based upon causal or even direct relationships with the resource usage under study and thus do not comport with ISO 14044, Section 4.3.4. Further, in some instances they provide results that not only differ from our causal allocations, but also from each other and there is no basis in logic or causality for choosing among these three methods. Nonetheless, we provided this capability in response to comments from a peer reviewer and to respond more fully to the expectations stated in ISO 14044, Section 4.3.4.1. We also present the results of a sensitivity analysis of our results using these alternative distribution keys in Section IV, below.")

I suggest something more explanatory and less defensive, such as:

"To accomplish this distribution by product, we use four alternative allocations. The first allocation is by volume-variable costs of each mail product and service. This allocates the environmental inventory based on the costs to the USPS for each category of mail. The other allocations are by weight, by piece, and by physical volume ("cube"). We also present the results of a sensitivity analysis of our results using these alternative allocations in Section IV, below."

Exhibits 11 and 12: Nice addition on recycling of mail.

Sensitivity Analysis: (page 17): The new text says:
"This exhibit shows that the estimated fuel and pollutant emissions associated with each mail product differ markedly depending upon the distribution key chosen. None of the three alternatives appears to

have a consistent relationship to the baseline key, which is based upon underlying causal factors. Accordingly, none of these more simple, and perhaps, intuitively obvious alternatives appear to be a potentially suitable substitute for the method that we have employed. It should be noted, however, that regardless of which distribution key is chosen to allocate USPS fuel use and related emissions among mail products, this choice has only limited impact on the overall results of the analysis. This is because the life cycle stages involving the Postal Service and its activities account for a relatively minor share of the life cycle total for most endpoints of interest."

Here again I suggest revising the paragraph to something that explains, rather than dismisses, the results. For example:

"This exhibit shows that the estimated fuel and pollutant emissions associated with each mail product differ markedly depending upon the distribution key chosen. When CO2 emissions are evaluated by weight or by volume, the relative contribution of standard mail, periodicals, and package services increase and the relative contributions of first class mail and all other USPS Services decrease. This is because first class mail and express mail generally has less mass and less volume than standard mail, periodicals, and packages. On the other hand, when CO2 emissions are allocated equally to each piece of mail, the relative contribution from both first class and standard mail increases, because of the relatively larger number of pieces in these categories compared to the USPS cost per piece."

p. 22. A discussion of the carbon uptake of trees has been added; in the previous version this was not discussed; it is indeed important to address this issue. However, the assessment does not appear to have correctly taken the carbon uptake of trees into account. The issue is not primarily one of what would happen if the trees were not cut to make paper. Rather, the primary issue is that the carbon contained in the trees has been removed from the atmosphere; this provides a negative carbon dioxide emission. At end of life this carbon is either re-released to the atmosphere as carbon dioxide (if the paper is combusted), or re-released as methane (as may occur with some of the paper in landfills if the landfill methane is not captured and combusted), or sequestered for long periods in the landfill. If most of the mail ends up in landfills, that could significantly reduce the net carbon dioxide emissions of the USPS.

Moreover the discussion of carbon sequestration in forests is not correct. Part of the carbon sequestered in forests is contained in the trees themselves. But a substantial part is contained in the soil. This entire section needs substantial revision.

In particular, the new text says " we have estimated that the 97,614 million pieces of this mail contain 1.925 million tons of paper and paper board. Multiplying the two yields an estimated quantity of CO_2 sequestration foregone attributable to First Class Mail of about 768 thousand tons. This is equivalent to nine percent of the total (8,502,785 metric tons) estimated by the LCI model for the balance of the life cycle." In contrast, a normal calculation would show that this 1.925 million tons of paper and paper board corresponds to removal from the atmosphere of, roughly, 6 million tons of CO2 from the atmosphere. This is balanced at end of life by some release to the atmosphere, depending on the disposal method, and here for the purpose of illustration (this should be calculated explicitly in the model) I will estimate this as roughly half, so that the total extraction from the atmosphere of 1.925 million tons of paper and board corresponds to about 3 million metric tons, or on the order of a third of the entire CO2 emissions.