2009

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Recommended Citation

Sawyer-Beaulieu, Susan S., "Gate-to-gate life cycle inventory assessment of North American end-of-life vehicle management processes" (2009). *Electronic Theses and Dissertations*. 8084.
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GATE-TO-GATE LIFE CYCLE INVENTORY ASSESSMENT OF NORTH AMERICAN END-OF-LIFE VEHICLE MANAGEMENT PROCESSES

by

Susan S. Sawyer-Beaulieu

A Dissertation
Submitted to the Faculty of Graduate Studies
through Civil and Environmental Engineering
in Partial Fulfillment of the Requirements for
the Degree of Doctor of Philosophy at the
University of Windsor

Windsor, Ontario, Canada

2009

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Direction du
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395, rue Wellington
Ottawa ON K1A 0N4
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Your file Votre référence
ISBN: 978-0-494-62872-0
Our file Notre référence
ISBN: 978-0-494-62872-0

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This dissertation incorporates the outcome of research undertaken with the supervision of Professor Edwin K. L. Tam. In all cases, the key ideas, primary contributions, experimental designs, data analysis and interpretation, were performed by the author of this dissertation. I am aware of the University of Windsor Senate Policy on Authorship and I certify that I have properly acknowledged the contribution of other researchers to my dissertation, where applicable. I certify that, with the above qualification, this dissertation, and the research to which it refers, is the product of my own work.

Further, this dissertation includes material from 3 original, co-authored papers that have been previously published in 2 refereed and 1 non-refereed conference proceedings, as follows:

Dissertation Chapter	Publication title/full citation	Publication Status
Chapter 2	Sawyer -Beaulieu, Susan and Edwin K.L. Tam, Applying Life Cycle Assessment (LCA) to North American End-of-Life Vehicle (ELV) Management Processes, SAE Technical Paper Series, 2005-01-0846, 2005 SAE World Congress, April, Detroit Michigan.	Published
Chapters 3, 4, 5 and 6	Sawyer -Beaulieu, Susan and Edwin K.L. Tam, Constructing a Gate-to-Gate Life Cycle Inventory (LCI) of End-of-Life Vehicle (ELV) Dismantling and Shredding Processes, SAE Technical Paper Series, 2008-01-1283, 2008 SAE World Congress, April, Detroit Michigan.	Published
Chapters 3, 4, 5, 6 and 7	Sawyer-Beaulieu, Susan and Edwin K.L. Tam, Analysis of North American End-of-Life Vehicle (ELV) Dismantling and Shredding Practices Using Life Cycle Assessment (LCA), Proceedings of the 9th International Automobile Recycling Congress, March, 11-13, 2009, Munich, Germany.	Published

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ABSTRACT

Life cycle analysis (LCA) will be used to increase the understanding of and consequently improve the end-of-life vehicle (ELV) management process currently employed in North America by:

- Showing the complete flow in ELV dismantling and shredding systems;
- Demonstrating the variability in the processes; and
- Managing this variability so as to close and surmount the gaps in these processes (*e.g.,* improve the recovery and recycling of scrap materials, such as plastics, from pre-shredder ELVs).

A literature review and case studies were conducted in cooperation with industrial recycling partners on operating ELV management facilities such as dismantlers, auto wreckers, and shredders. Successful ELV practices, unit operations, and/or technologies were identified and their practical constraints and issues of concern examined. Using the case study information and supplemental data, a life cycle inventory (LCI) of typical ELV management processes has been constructed.

The LCA approach is used to examine the efficiencies of the vehicle end-of-life (VEOL) dismantling process. The mass flows of parts and/or materials (types and quantities) that are removed preferentially and directed for reuse, remanufacturing, "pre-shredder" recycling, and/or disposal, were assessed relative to the amount of vehicles entering the end-of-life phase. Similarly, dismantling process inefficiencies are characterized in terms of the mass flow of leftover ELV hulks and dismantled parts purged from inventory that are shipped for shredding and metals recovery.

Shredding process efficiencies and inefficiencies are assessed in terms of both the flow of shredded ferrous and non-ferrous metals products recovered, as well as flow of shredder residue (SR) generated and directed for disposal, relative to the quantity of material directed for shredding.

As much as 116.3 kg/tonne (11.6% weight) of the ELVs entering the dismantling process are recovered and directed for either, reuse, remanufacturing or recycling, including the recovered fluids; 5.7% weight of the ELVs processed consisted of parts recovered for reuse. Of the materials directed for shredding - ELV hulks and “scrapped-out” parts and other oversized, metals-rich scrap - 808 kg/tonne (80.8% weight) are recovered in the shredded ferrous and non-ferrous metals products and 192 kg/tonne (19.2% weight) is accounted for in the shredder residue.

DEDICATION

To my husband, Pierre,
for your unwavering faith and confidence,
and to my mother, Audrey,
my biggest fan.

ACKNOWLEDGEMENTS

I gratefully acknowledge the support and guidance of Dr. Edwin Tam. I also would like to thank the environmental, civil and automotive engineering laboratory technicians for their support and assistance during the time spent completing the Parts Mass Study work.

I would like to thank my husband, Pierre Beaulieu, for his resolute faith, encouragement, and assistance through the duration of the research.

I wish to also acknowledge the generous support provided by:

- AUTO21 Network of Centres of Excellence Project (B06-BLC)
- United States Council for Automotive Research (USCAR) Vehicles Recycling Partnership (VRP)
- Standard Auto Wreckers
- ACME Auto Parts
- Dover Auto Wreckers Ltd.
- Essex Auto Wreckers
- And the other 7 industrial partners who helped make this research possible.

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1 INTRODUCTION

Life cycle assessment (LCA) can be used to analyze vehicle end-of-life (VEOL) management processes. LCA is the 'cradle-to-grave' analysis of the impacts of a product or process during its entire life cycle, from raw materials production to manufacture, use and then end-of-life. The end-of-life (EOL) phase is the least studied phase of the vehicle life-cycle. The processes currently used for vehicle end-of-life management in Canada and the U.S. are principally dismantling and shredding. They are typically perceived as distinct processes, and each has distinct challenges. Typically end-of-life vehicles (ELVs) are processed by dismantling, followed by shredding.

In dismantling, vehicle parts and materials are removed for direct reuse, for remanufacturing and reuse, or for recycling. Dismantling may be perceived as a non-preferred alternative, compared to shredding, because it is principally a manual process, which can be costly in the North American/western labour market. In addition, because dismantling is promoted by incorporating design-for-recycling (DfR) and design-for-disassembly (DfD) principles in original equipment manufacturer (OEM) vehicle design and manufacturing, it may represent added costs to the automotive manufacturing process. However, there has been no exhaustive assessment of the dismantling process. Automobiles may be considered too complex and dissimilar to recycle efficiently. Further promoting the recycling of vehicles will require additional information about dismantling, including its benefits and impacts, its efficiencies and inefficiencies, and its relation to other ELV management processes.

Shredding involves the mechanized processing of ELV hulks, and other metal–rich scrap materials, using a hammer-mill. Shredder residue (SR) is a waste product of the shredding process. Managing it can be a challenge because of the volumes generated, the contaminants or toxic substances that it may contain, and the recyclable materials in it that may be unrecoverable. Shredder residue solutions principally focus on post-shredding solutions, most of which have not been commercially successful or proven to date. An alternative approach to improving shredding efficacy would be to optimize dismantling prior to shredding, with the goals of:

- reducing SR volumes;
- increasing materials recovery; and
- reducing SR contaminants.

A thorough consideration of automotive end-of-life issues will address additional questions. Is the industry limited to the use of traditional manual dismantling methods for recovery of ELV parts and materials for recycling, and can these methods be enhanced, such as through alternative materials identification methods? Are there any intermediate mechanisms or operations that can be used to liberate and recover ELV parts/materials for recycling after manual dismantling, but prior to sending the ELV hulk to the shredder?

An LCA of the VEOL dismantling and shredding process should yield an improved ELV management system for a North American operation. It can also expand the applicability of LCA as an analysis and design tool. An LCA scoped down to cover one process or one phase in the life cycle is referred to as 'gate-to-gate' LCA and is defined as the analysis of a process, from the gate through which the materials enter the process to the gate where the products leave [Graedel and Allenby, 2003]. This research undertakes the establishment and assessment of a comprehensive gate-to-gate life cycle inventory (LCI) of ELV dismantling and shredding processes, which is the necessary first step of conducting a life cycle assessment of VEOL. The research objectives are therefore to:

1) Identify and quantify the efficiencies and inefficiencies of the ELV dismantling and shredding processes relative to their materials throughput. Dismantling efficiencies will be assessed with respect to:

    a) the flows of parts and/or materials that are preferentially removed, per tonne of ELVs processed, and directed for reuse, remanufacturing and "pre-shredder" recycling, and

    b) the flow of hazardous or environmentally sensitive parts and/or materials recovered, per tonne of ELVs processed, and directed for reuse, recycling or disposal.

    Dismantling inefficiencies will be assessed with respect to:

    a) the flow of ELV hulks and parts that are leftover from dismantling, per tonne of ELVs processed, and sent for shredding (and metals recovery), and .

    b) the flow of inventoried parts and/or materials that are initially removed during dismantling, but subsequently deleted or purged from inventory (*i.e.,* "scrapped-out") , per tonne of ELVs processed, and discarded with ELV hulks for shredding.

Shredding efficiencies will be assessed with respect to the flow of shredded ferrous and non-ferrous metals recovered per tonne of shredder infeed. Shredder inefficiencies will be assessed with respect to the flow of shredder residue (SR) generated per tonne of shredder infeed and typically directed for disposal.

By assessing the proportions of materials recovered from ELVs and directed for reuse, remanufacturing, pre-shredder recycling and post-shredder recycling, North American ELV management systems and recycling rates may be benchmarked against legislated ELV management practices and recycling rates used in other countries, such as those dictated under the EU ELV Directive 2000/53/EC [EU, 2000] or Japan's 2002 ELV Recycling Law. The results of this research can be of value to North American policy makers, should similar legislation be considered for the management of ELVs in Canada and the US. This work could help address policy related questions on the efficacy of market based VEOL recycling programs versus mandated or legislated VEOL recycling programs.

2) Identify and quantify energy and water inputs, and waste water outputs for ELV dismantling and shredding processes.
3) Identify and quantify air emissions from ELV dismantling and shredding processes.
4) Characterize the average vehicle currently being retired to the end-of-life phase, according to weight, class, and age.
5) After completing the proposed LCI, consider how the practices and procedures employed to develop this LCI could be then generalized or adapted to facilitate a "systematic approach" to gathering, assessing, and interpreting other similar life cycle inventory situations.

2 LITERATURE REVIEW

Literature reviews have identified multiple variables associated with the ELV management processes of dismantling, shredding, baling, and shredder residue processors, currently in use. These variables include:

- existing practices;
- issues of concern;
- types, amounts, and proportions of materials used in vehicles;
- materials, particularly plastics, currently recovered from ELVs by dismantlers and prior to shredding/baling (if any), *i.e.,* types, amounts, proportions, mechanical/physical associations;
- practical constraints to materials recovery, particularly plastics, from ELVs and shredder residue (SR);
- regulatory aspects of ELV management; and
- LCAs that have been conducted with respect to ELV management processes, including issues associated to LCA practices.

2.1 End-of-Life Vehicle (ELV) management in North America

Figure 1 illustrates a simplified schematic diagram of a typical ELV management process in North America. In general, ELVs in North America are processed by dismantling, then shredding, followed by separation of the low-density, non-metallic materials from the higher-density, metal-dominant fraction using air classification methods.

The metal fraction is subsequently processed by magnetic separation to separate the ferrous metals, *e.g.,* cast iron, carbon steel, from the non-ferrous and non-magnetic metals, *e.g.*, aluminum, copper, zinc, nickel, stainless steel, and lead. The low density, non-metallic materials may be further processed using a variety of separation methods to improve metal recovery.

The recovered ferrous and non-ferrous metals are recycled. The ferrous metals fraction is typically relatively free of impurities, with less than one percent fines, rust and non-ferrous metals. It is recycled as alternative feed stock for steel mills [Staudinger and Keoleian, 2001]. The non-ferrous metal fraction usually requires additional processing and treatment to separate the materials into individual metal fractions that are of sufficient purity for subsequent recycling by metal refining.

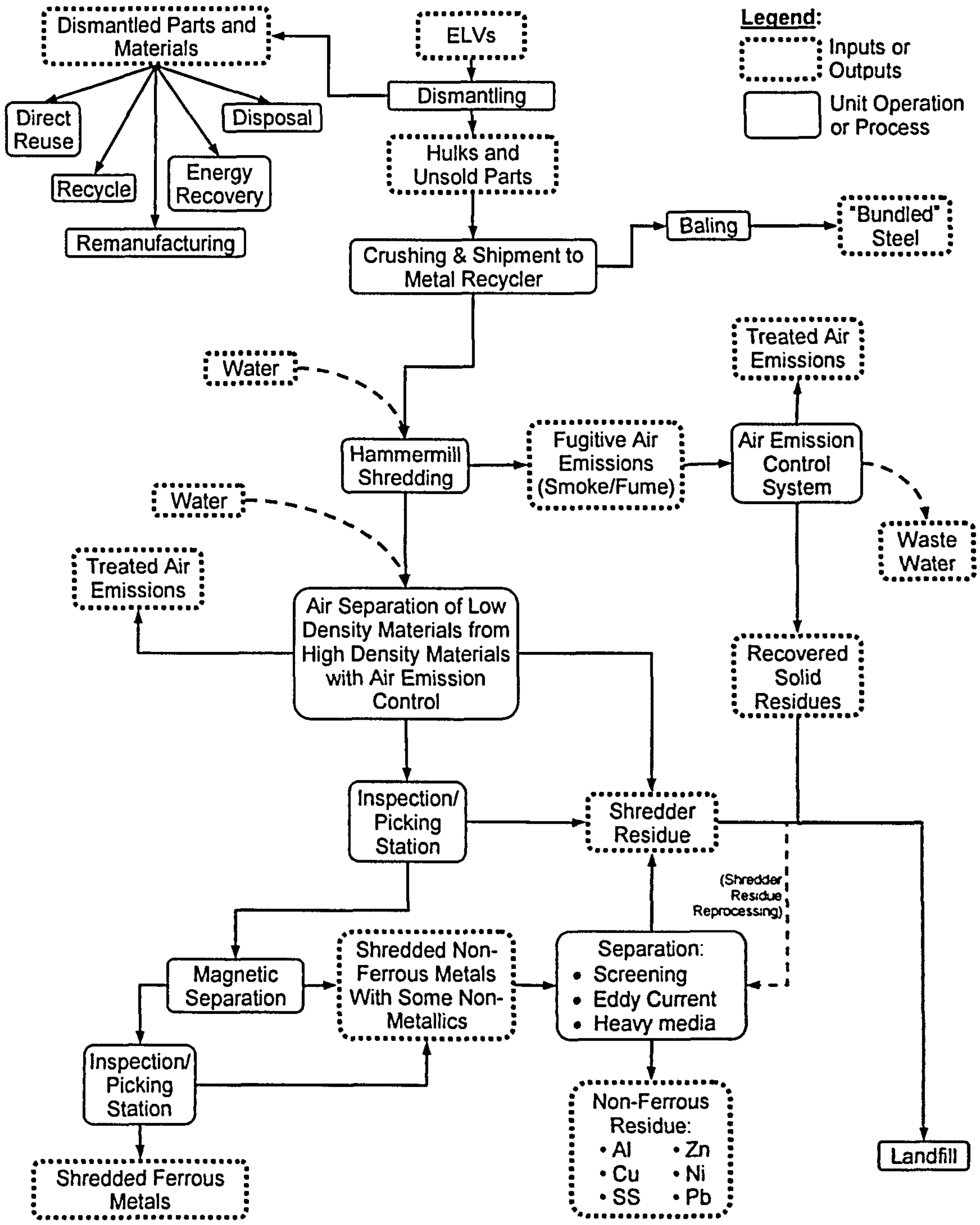


Figure 1 Simplified schematic diagram of a typical ELV management process.

The non-metallic SR characteristically consists of plastics, glass, rubber, textiles and carpeting, ceramics, paper, etc. SR is routinely disposed of by landfilling. However, alternative management schemes have been, either, proposed, tested or used in a limited fashion. These alternatives will be addressed later.

Table 1 summarizes typical automobile compositions (excluding battery, fluids and tires) from the 1960s to 1995; Figure 2 illustrates the trends in changing automobile composition over time. As shown in Figure 2, the ferrous metal content of automobiles has been decreasing over time and the non-ferrous metal and plastic content increasing. For typical vehicle retirement ages of between 10-15 years [Staudinger and Keoleian, 2001], the composition of the majority of vehicles being retired currently is expected to be comparable to that of vehicle models between 1989 and 1995. As a result, it is expected that a majority of current ELVs would have a combined ferrous and non-ferrous metal content of approximately 74 to 77% by weight and a non-metallic material content of 17% to 22% by weight.

Table 1 Automobile composition from 1960s to 1990s

Material	% Weight Distribution of Materials in Automobiles						
	Circa 1960(1)	Mid 1970s(2)	Early 1980s(3)	1980(4)	1985(5)	1989(6)	1995(7)
Ferrous Metals	81.0	78.0	69.5	71.3	68.5	69.6	64.5
Non-Ferrous Metals (Al, Cu, Zn, Pb)	4.2	4.3	5.5	6.4	7.6	7.1	9.0
Total Metals	85.2	82.3	75.0	77.7	76.1	76.7	73.5
Inorganics, including Glass	2.7	2.9	3.4	2.7	2.4	2.7	3.1
Organics, including Plastic, Rubber(8) (% as Plastic)	7.2 (0.7)	10.3 (3.2)	13.0 (5.2)	14.1 (6.6)	15.4 (7.9)	14.7 (7.1)	18.5 (9.4)
Total Non-Metals	9.9	13.2	16.9	16.8	17.8	17.4	21.6
Fluids(9)	4.9	4.5	8.6	5.6	6.1	5.8	4.8
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Notes: (1) Weight of battery not included; from Dean *et. al.*, 1985.
(2)Average for 5 U.S. automobiles; weight of battery not included; from Dean *et al.*, 1985.
(3)Average for 4 Japanese automobiles; weight of battery not included; from Dean *et al.*, 1985.
(4)Represents 1980 Ford automobile; from Ford Motor Company, Phoenix Quarterly, Spring 1987 [MOE, 1991].
(5)Represents 1985 Ford automobile; from Ford Motor Company, Phoenix Quarterly, Spring 1987 [MOE, 1991].
(6) Represents average automobile; from Wards Automotive Yearbook 1975-1990 [AISI, 1992].
(7) 1995 model generic family sedan [Sullivan *et al.*, 1998].
(8) Estimated weight of tires = 45 kg (100 lbs) [Keoleian and Kar, 2003; Sullivan, 1998]
(9)Estimated weight of fluids = 82 kg (180 lb); from Wards Automotive Yearbook 1975-1990 [AISI, 1992].

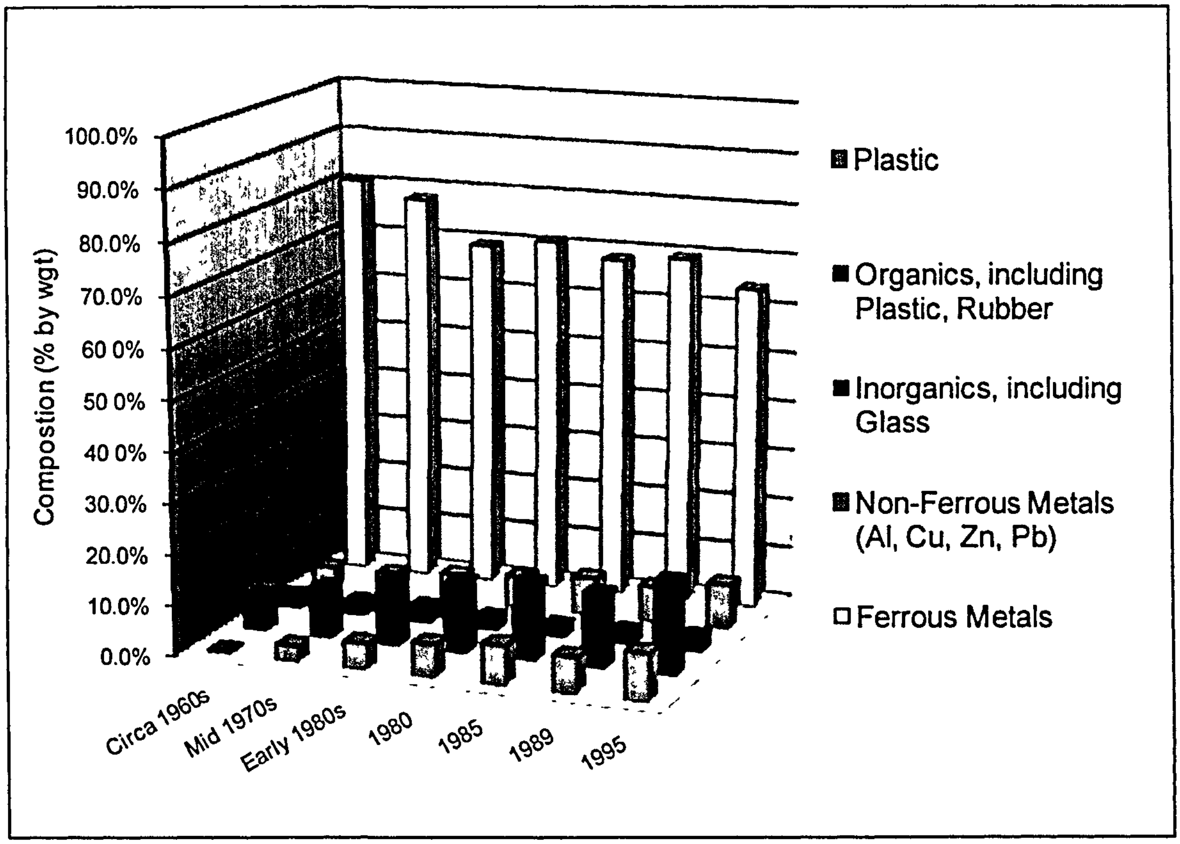


Figure 2 Changes in Automobile Composition versus Model Year.

The Steel Recycling Institute recently reported that over 12.91 million metric tonnes (14.2 million tons) of ELV-derived scrap steel was recycled in the US in 2003 [SRI, 2004]. Assuming an average 1989-1995 model passenger motor vehicle having an average ferrous metal content of approximately 67% and an average "equivalent passenger vehicle" weight of 1455 kg (3200 lbs) [Staudinger and Keoleian, 2001], then the 12.9 million metric tonnes of scrap steel represents an estimated 13.25 million retired motor vehicles having a total combined weight in excess of 19.2 million metric tonnes (21.2 million tons). Of the 19.2 million metric tonnes, it is estimated that 6% are abandoned [Staudinger and Keoleian, 2001; AAMA, 1997] and therefore, the balance, 94%, or 18.4 million metric tonnes, are estimated to be permanently retired and recycled as ELVs.

In 2003 approximately 18.9 million roadway motor vehicles were registered in Canada [Statistics Canada, 2004]. To provide a preliminary estimate of the number of motor vehicles retired in Canada annually, it is not unreasonable to expect that Canadian vehicle retirement rates approximate U.S. vehicle retirement rates. Using U.S. Department of Energy cited data [USDOE, 2000] of available vehicle registration and sales data in the U.S. from 1989 to 1998, Staudinger and Keoleian [2001] showed that on average, the 11.4 million vehicles retired annually, represent approximately 6% of all registered vehicles used annually, or 190.6 million. Assuming 6% of all registered roadway vehicles in Canada are retired annually, and 6% of all retired vehicles are abandoned, it is estimated that in excess of 1.1 million vehicles were permanently retired and recycled as ELVs in Canada in 2003, or 1.6 million metric tonnes (assuming an average "equivalent passenger vehicle" weight of 1455 kg (3200 lbs), as used above).

When shredded, up to 95% of an ELV's ferrous and non-ferrous metals content is recycled [Day, 1994], which amounts to approximately 72% of the total ELV's weight on average (assuming the 74% to 77% weight ferrous and non-ferrous metal content mentioned previously). In Canada and the U.S., this equates to the expected generation of more than 14.4 M metric tonnes of recyclable ferrous and non-ferrous metals and 5.6 M metric tonnes of SR annually. Notably, plastics make up roughly one third of SR, representing an annual loss of more than 1.9 million metric tonnes of a valuable non-renewable resource.

The composition of a 1995 generic Intrepid/Lumina/Taurus family sedan is illustrated in Table 2. This generic vehicle is a synthesis of three comparable 1995 vehicles: the Dodge Intrepid, the Chevrolet Lumina, and the Ford Taurus. The mass, composition and material type for each part/component was generated by dividing the vehicle into three sections of roughly equal weight, with one section modeled using Chevrolet Lumina parts, the second modeled using Dodge Intrepid parts and the third using Ford Taurus parts [Sullivan *et. al.*, 1998]. The United States Automotive Materials Partnership Life Cycle Assessment Special Topics Group (USAMP/LCA) developed this vehicle as a part of a life cycle inventory conducted to benchmark the environmental (not cost) performance of a generic vehicle. The benchmark could then serve as a basis of comparison for environmental performance estimates for new and future vehicles [Sullivan *et. al.*, 1998]. As seen in Table 2, the generic vehicle is approximately 9% plastics, 73% ferrous and non-ferrous metals, 5% fluids and 13% other (principally non-metallic, non-plastic) materials by weight.

Table 2 Material Composition of a 1995 Generic Family Sedan [Sullivan *et. al.*, 1998]

Material Category	Material	Mass (kg)	% wgt of Material Category	% wgt of Vehicle
Plastics	ABS (Acrylonitrile Butadiene Styrene)	9.7	6.840%	0.634%
	ABS-PC blend (Acrylonitrile Butadiene Styrene-Polycarbonate blend)	2.8	1.974%	0.183%
	Acetal	4.7	3.314%	0.307%
	Acrylic Resin	2.5	1.763%	0.163%
	ASA (Acrylonitrile Styrene Acrylate)	0.18	0.127%	0.012%
	Epoxy Resin	0.77	0.543%	0.050%
	PA 6 (Polyamide 6)	1.7	1.199%	0.111%
	PA 66 (Polyamide 66)	10	7.052%	0.653%
	PA 6-PC blend (Polyamide-Polycarbonate blend)	0.45	0.317%	0.029%
	PBT (Polybutylene terephthalate)	0.37	0.261%	0.024%
	PC (Polycarbonate)	3.8	2.680%	0.248%
	PE (Polyethylene)	6.2	4.372%	0.405%
	PET (Polyethylene terephthalate)	2.2	1.551%	0.144%
	Phenolic Resin	1.1	0.776%	0.072%
	Polyester Resin	11	7.757%	0.719%
	PP (Polypropylene)	25	17.629%	1.633%
	PP foam	1.7	1.199%	0.111%
	PP-EPDM blend (Polypropylene-ethylene propylene diene monomer blend)	0.1	0.071%	0.007%
	PPO-PC blend (Polyphenylene Oxide-Polycarbonate blend)	0.025	0.018%	0.002%
	PPO-PS blend (Polyphenylene Oxide-Polystyrene blend)	2.2	1.551%	0.144%
	PS (Polystyrene)	0.0067	0.005%	0.000%
	PUR (Polyurethane)	35	24.681%	2.286%
	PVC (Polyvinyl Chloride)	20	14.103%	1.307%
	TEO (Thermoplastic Elastomeric Olefin)	0.31	0.219%	0.020%
	Subtotal	141.81	100.00%	9.264%
Non-Ferrous Metals	Aluminum Oxide	0.27	0.197%	0.018%
	Aluminum (cast)	71	51.680%	4.638%
	Aluminum(extruded)	22	16.014%	1.437%
	Aluminum (rolled)	3.3	2.402%	0.216%
	Brass	8.5	6.187%	0.555%
	Chromium	0.91	0.662%	0.059%
	Copper	18	13.102%	1.176%
	Lead	13	9.463%	0.849%
	Platinum	0.0015	0.001%	0.000%
	Rhodium	0.00029	0.000%	0.000%
	Silver	0.0034	0.002%	0.000%
	Tin	0.067	0.049%	0.004%
	Tungsten	0.011	0.008%	0.001%
	Zinc	0.32	0.233%	0.021%
	Subtotal	137.38	100.000%	8.975%
Ferrous Metals	Iron (Ferrite)	1.5	0.152%	0.098%
	Iron (Cast)	132	13.381%	8.623%
	Iron (Pig)	23	2.331%	1.503%
	Steel (cold rolled)	114	11.556%	7.447%
	Steel (EAF)	214	21.693%	13.980%
	Steel (galvanized)	357	36.189%	23.322%
	Steel (hot rolled)	126	12.772%	8.231%
	Steel (stainless)	19	1.926%	1.241%
	Subtotal	986.5	100.000%	64.445%
Fluids	Auto Trans. Fluid	6.7	9.055%	0.438%
	Engine Oil	3.5	4.730%	0.229%
	Ethylene Glycol	4.3	5.812%	0.281%
	Gasoline	48	64.874%	3.136%
	Glycol Ether	1.1	1.487%	0.072%
	Refrigerant	0.91	1.230%	0.059%
	Water	9	12.164%	0.588%
	Windshield Cleaning Additives	0.48	0.649%	0.031%
	Subtotal	73.99	100.000%	4.834%
Other Materials	Adhesive	0.17	0.089%	0.011%
	Asbestos	0.4	0.209%	0.026%
	Bromine	0.23	0.120%	0.015%
	Carpeting	11	5.757%	0.719%
	Ceramic	0.25	0.131%	0.016%
	Charcoal	0.22	0.115%	0.014%
	Corderite	1.2	0.628%	0.078%
	Desiccant	0.023	0.012%	0.002%
	Fiberglass	3.8	1.989%	0.248%
	Glass	42	21.980%	2.744%
	Graphite	0.092	0.048%	0.006%
	Paper	0.2	0.105%	0.013%
	Rubber (EPDM)	10	5.233%	0.653%
	Rubber (extruded)	37	19.363%	2.417%
	Rubber (tires)	45	23.550%	2.940%
	Rubber (other)	23	12.037%	1.503%
	Sulfuric Acid- in battery	2.2	1.151%	0.144%
	Textile Fibers	12	6.280%	0.784%
	Wood	2.3	1.204%	0.150%
	Subtotal	191.085	100.000%	12.483%
	Total	1530.7699		100.000%

With respect to materials composition of automotive parts, components or assemblies, very little information has been found in published literature. In one paper, Johnson and Wang [2002], summarized the weights of 56 resellable or remanufacturable parts and assemblies (RRPA) for an early 1990s-model mid-sized family sedan. These RRPA weights (total part weight, weight of metallic materials and weight of non-metallic materials) are summarized in Table 3 and are based on a vehicle having an original weight of 1424.82 kg., composed of 21.05% (299.92 kg) non-metals and 78.95% (1124.90 kg) metals by weight [Johnson and Wang, 2002]. These 56 RRPAs represent approximately 60% of the original vehicle by weight.

Although the ELV management industry is well established in North America and the processing technologies are generally understood, specifics about each stage or unit operation of the ELV management process are not well documented, according to the literature reviewed. It is expected that ELV dismantling and shredding practices and post-shredder recovery/treatment processes will vary somewhat from region to region, as influenced by:

- regulatory constraints (federal, provincial/state, municipal);
- market supply and demand for used car parts;
- market value of the particular parts recovered;
- supply and demand of ELV hulks as shredder feedstock;
- shredder feed material specifications, *i.e.,* acceptable versus non-acceptable materials;
- quality control of shredder feed materials, *i.e.,* inspection, sampling, testing of materials destined for shredding;
- shredder though-put capacity;
- shredded metal product quality;
- foundry and steel mill feedstock specifications;
- quality control of foundry and steel mill feedstock;
- supply and demand of ferrous metals as alternative melting units for steel mills and foundries;
- disposal/management options for residues generated during dismantling and shredding.

Table 3 Materials Composition of 56 Resellable or Remanufacturable Parts and Assemblies (RRPA) for an Early 1990s-Model Mid-Sized Family Sedan [Johnson and Wang, 2002]

Resellable or Remanufacturable Part or Assembly (RRPA)	Mass of RRPA	Metallic Mass				Non-Metallic Mass			
	kg	kg	% of Specific RRPA Mass	% of Original Vehicle Mass	% of Total Vehicle Metallic Mass	kg	% of Specific RRPA Mass	% of Original Vehicle Mass	% of Total Vehicle Non-Metallic Mass
Gas tank	12 727	12 727	100 000%	0 893%	1 131%	0	0 000%	0 000%	0 000%
Front door right	38 4	24 415	63 581%	1 714%	2 170%	13 985	36 419%	0 982%	4 663%
Front door left	34 88	24 775	71 029%	1 739%	2 202%	10 105	28 971%	0 709%	3 369%
Door rear right	25 499	18 687	73 285%	1 312%	1 661%	6 812	26 715%	0 478%	2 271%
Door rear left	25 499	18 687	73 285%	1 312%	1 661%	6 812	26 715%	0 478%	2 271%
Seat front right	21 719	16 856	77 609%	1 183%	1 498%	4 863	22 391%	0 341%	1 621%
Seat front left	27 24	21 518	78 994%	1 510%	1 913%	5 722	21 006%	0 402%	1 908%
Seat rear bottom	6 64	2 907	43 780%	0 204%	0 258%	3 733	56 220%	0 262%	1 245%
Seat rear back	7 199	0 032	0 445%	0 002%	0 003%	7 167	99 555%	0 503%	2 390%
Seatbelt front right	1 38	0 907	65 725%	0 064%	0 081%	0 473	34 275%	0 033%	0 158%
Seatbelt front left	1 38	1 033	74 855%	0 073%	0 092%	0 347	25 145%	0 024%	0 116%
Third brake light	0 34	0 06	17 647%	0 004%	0 005%	0 28	82 353%	0 020%	0 093%
Seatbelt rear right	0 94	0 679	72 234%	0 048%	0 060%	0 261	27 766%	0 018%	0 087%
Seatbelt rear left	0 94	0 679	72 234%	0 048%	0 060%	0 261	27 766%	0 018%	0 087%
Steering column assembly	10 06	8 714	86 620%	0 612%	0 775%	1 346	13 380%	0 094%	0 449%
Tail light cover right	0 54	0	0 000%	0 000%	0 000%	0 54	100 000%	0 038%	0 180%
Tail light cover left	0 52	0	0 000%	0 000%	0 000%	0 52	100 000%	0 036%	0 173%
Tail light cover centre	1 28	0	0 000%	0 000%	0 000%	1 28	100 000%	0 090%	0 427%
Fascial rear lower (IDIS part)	8 56	0	0 000%	0 000%	0 000%	8 56	100 000%	0 601%	2 854%
Energy absorber rear left	2 46	0	0 000%	0 000%	0 000%	2 46	100 000%	0 173%	0 820%
Energy absorber rear right	2 46	0	0 000%	0 000%	0 000%	2 46	100 000%	0 173%	0 820%
Deck lid (trunk)	13 26	13 1274	99 000%	0 921%	1 167%	0 1326	1 000%	0 009%	0 044%
Battery (IDIS part)	20	20	100 000%	1 404%	1 778%	0	0 000%	0 000%	0 000%
Air cleaner assembly (IDIS part)	1 86	0 06	3 226%	0 004%	0 005%	1 8	96 774%	0 126%	0 600%
Heat box assembly	8 64	4 18	48 380%	0 293%	0 372%	4 46	51 620%	0 313%	1 487%
ECU	1 08	0 324	30 000%	0 023%	0 029%	0 756	70 000%	0 053%	0 252%
Brake booster	4 14	3 519	85 000%	0 247%	0 313%	0 621	15 000%	0 044%	0.207%
Cooling fan shroud assembly	3 68	3 68	100 000%	0 258%	0 327%	0	0 000%	0 000%	0 000%
Cruise servo	1 08	0 216	20 000%	0 015%	0 019%	0 864	80 000%	0 061%	0 288%
Wheel rear right	16 1	7 18	44 596%	0 504%	0 638%	8 92	55 404%	0 626%	2 974%
Wheel rear left	16 18	7 18	44 376%	0 504%	0 638%	9	55 624%	0 632%	3 001%
Windshield wiper motor	1 98	1 98	100 000%	0 139%	0 176%	0	0 000%	0 000%	0 000%
Wind shield front	11 76	0	0 000%	0 000%	0 000%	11 76	100 000%	0 825%	3 921%
FC radiator heat exchanger	4 76	4 048	85 042%	0 284%	0 360%	0 712	14 958%	0 050%	0 237%
FC a c condenser	2 12	2 12	100 000%	0 149%	0 188%	0	0 000%	0 000%	0 000%
FC marker light front left	0 34	0	0 000%	0 000%	0 000%	0 34	100 000%	0 024%	0 113%
FC marker light front right	0 34	0	0 000%	0 000%	0 000%	0 34	100 000%	0 024%	0 113%
FC light headlight left	0 86	0 02	2 326%	0 001%	0 002%	0 84	97 674%	0 059%	0 280%
FC light headlight right	0 86	0 02	2 326%	0 001%	0 002%	0 84	97 674%	0 059%	0 280%
FC light front assembly centre	1 06	0	0 000%	0 000%	0 000%	1 06	100 000%	0 074%	0 353%
FC fascial front lower (IDIS part)	9 68	0	0 000%	0 000%	0 000%	9 68	100 000%	0 679%	3 227%
FC energy absorber front right	2 5	2 5	100 000%	0 175%	0 222%	0	0 000%	0 000%	0 000%
FC energy absorber front left	2 5	2 5	100 000%	0 175%	0 222%	0	0 000%	0 000%	0 000%
FC hood	21 92	21 28	97 080%	1 494%	1 892%	0 64	2 920%	0 045%	0 213%
Drive train a c compressor	6 36	6 36	100 000%	0 446%	0 565%	0	0 000%	0 000%	0 000%
Drive train alternator	6 58	6 58	100 000%	0 462%	0 585%	0	0 000%	0 000%	0 000%
Drive train power steering	6 34	6 02	94 953%	0 423%	0 535%	0 32	5 047%	0 022%	0 107%
Drive train starter	3 5	3 5	100 000%	0 246%	0 311%	0	0 000%	0 000%	0 000%
Drive train engine	200	180	90 000%	12 633%	16 001%	20	10 000%	1 404%	6 668%
Drive train transmission	94 555	94 555	100 000%	6 636%	8 406%	0	0 000%	0 000%	0 000%
Drive train wheel right	16 28	7 18	44 103%	0 504%	0 638%	9 1	55 897%	0 639%	3 034%
Drive train- wheel left	16 28	7 18	44 103%	0 504%	0 638%	9 1	55 897%	0 639%	3 034%
Drive train cradle suspension assy	107 959	107 959	100 000%	7 577%	9 597%	0	0 000%	0 000%	0 000%
Catalytic converter	11 709	11 709	100 000%	0 822%	1 041%	0	0 000%	0 000%	0 000%
IP (intrument panel) radio	1 48	1 184	80 000%	0 083%	0 105%	0 296	20 000%	0 021%	0 099%
IP (intrument panel) cluster	1 54	0	0 000%	0 000%	0 000%	1 54	100 000%	0 108%	0 513%
Totals	849 946	678 8374		47 644%	60 347%	171 1086		12 009%	57 051%

2.2 ELV Dismantling Practices

ELV dismantlers generally fall into one of two categories:

1) low-inventory, large-volume turnover dismantlers; and
2) large-inventory, low-volume turnover dismantlers, *e.g.*, traditional "mom-and-pop-type" salvage/junk yards.

Low-inventory, large-volume turnover dismantlers include retail/wholesale businesses that remove and inventory parts (principally high-value parts) for resale for direct reuse, or remanufacture for reuse [Keoleian *et. al.*, 1997; Staudinger and Keoleian, 2001; RCO, 1999]. Computer based parts inventories are typically maintained and used to sell parts and to facilitate in deciding what to dismantle [RCO, 1999]. These operations target late-model ELVs and operate on a relatively high volume, quick turnover basis [Staudinger and Keoleian, 2001].

In contrast, traditional large-inventory, low-volume turnover dismantlers tend to maintain larger inventories of recovered parts and operate on a relatively slow, low volume turnover basis, storing ELVs while parts from them are gradually scavenged and sold. Staudinger and Keoleian [2001] indicate traditional "mom-and-pop-type" salvage/junk yards fall into this category and are typically low-tech operations where detailed parts inventories are generally not maintained. More recently, however, traditional low-volume turnover dismantlers are adopting the use of computer-based parts inventories to facilitate and control the parts dismantling and selling process.

ELVs are dismantled for recovery of parts that may be sold for direct reuse, such as un-deployed air bags, wheels, and body panels used to repair collision-damaged vehicles [Staudinger and Keoleian, 2001], and parts that may be remanufactured for reuse. Johnson and Wang [2002] cite the following as "traditional" remanufacturable assemblies:

- air conditioner compressor
- alternator
- brake booster
- starter
- engine
- transmission
- heat box assembly blower motor
- power steering pump
- cooling fan shroud assembly
- windshield wiper motor
- electronic control unit (ECU), *i.e.*, computer

Parts and materials will also be recovered from ELVs both for recycling, such as fluids (engine oil, transmission fluid, brake fluid, steering fluid, ethylene glycol, windshield washing fluid, gasoline), refrigerant, batteries, catalytic converters, steel fuel tanks, tires, aluminum and copper parts [Staudinger and Keoleian, 2001; RCO, 1999], as well as for energy recovery, *e.g.,* tires. Other ELV parts and/or materials may be removed for disposal, such as plastic fuel tanks and mercury switches [Staudinger and Keoleian, 2001].

What is left of an ELV at the end of the dismantling process – typically called the "hulk" – is commonly flattened using a car crusher and subsequently shipped to a metals recycling facility for shredding. Hulks are flattened to densify them and hence reduce the transportation costs.

Figure 3 illustrates an example of a dismantling process identifying parts and/or materials destined for direct reuse, for remanufacturing, for "direct" recycling (but not for metal shredding), materials for scrap metal shredding and materials for treatment and disposal. The process flow sheet in Figure 3 was prepared based on the typical sequence of dismantling steps identified in the research by Paul, Chung and Raney [2004] to evaluate the actual recyclability of Honda vehicles. The dismantling sequence used in this research was selected and performed by an experienced dismantler mechanic and involved as many as 55 steps [Paul, *et al.*, 2004]. Dismantling activities involving the removal and recovery of fluids and materials of concern (*e.g.,* batteries, un-deployed air bags) are commonly referred to as pretreatment steps; but this terminology is not necessarily indicative of the order in which these steps are performed. Generally the pretreatment measures are activities that are performed as part of the dismantling process to alleviate environmental or safety concerns associated with the shredding of ELVs [Paul, *et al.*, 2004; Sawyer-Beaulieu and Tam, 2005]. What has not been well documented in published literature is how "typical" this sequence is to commercial dismantling operations (see Figure 3). The available literature does not indicate if these steps are common to most dismantling operations, or if there is a specific "core" sequence of steps used by dismantlers, with other parts removal steps being used if circumstances are favorable or mandatory.

In the research by Paul *et al.* (2004), eighteen Honda vehicles of various models (Accords, Civics, a Prelude and an Acura TL) and models years (1982 to 2001) were dismantled by experienced dismantler mechanics. The dismantling of each vehicle involved removing fluids and materials of concern (*e.g.,* battery, airbags, gasoline tank and tires), parts for reuse (including remanufacturing) and parts for recycling (*e.g.,* catalytic converters, calipers, engine accessories and brake rotors).

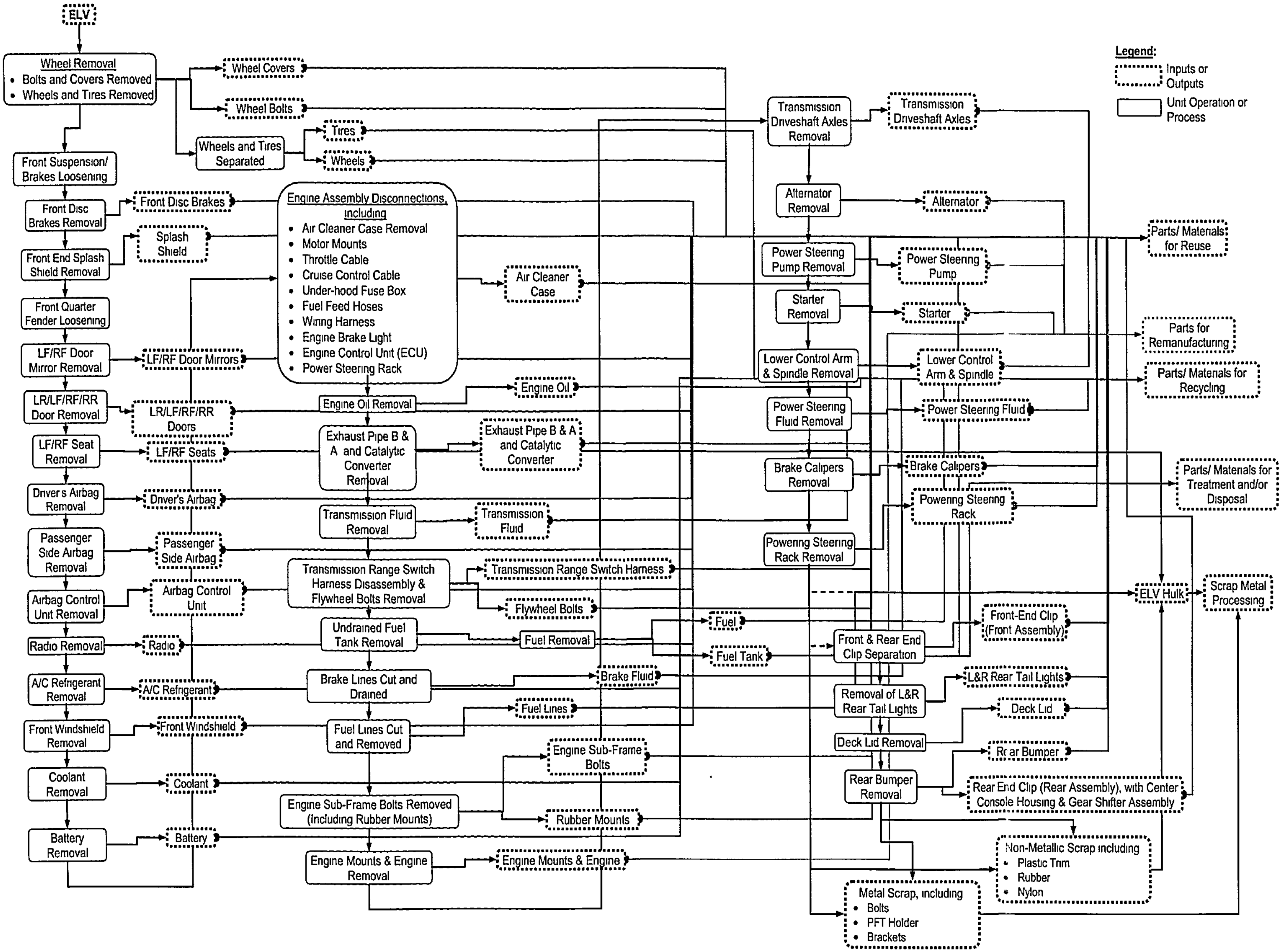


Figure 3 Typical Dismantling Process (adapted from Paul .*et al.*, 2004).

Parts and components were selected for removal, by inventory control managers, based on market demand, existing inventory and recent sales. Between 13 and 75 parts were removed from each vehicle for reuse.

Weights were measured and recorded of each original vehicle for all parts/components and fluids recovered from each vehicle, as well as for the resulting stripped hulks. Material(s) makeup was qualitatively assessed and recorded for each fluid, part, component or other material removed from the vehicle, as either Fluid, Metal, Plastics, Rubber, Glass or Other (*i.e.,* foam, fabric, mixed materials, ceramic, wood or any other small quantity material). Material disposition was also recorded for each fluid, part, component or other material removed to allow their identification as reused, recycled (includes remanufacturing, material recycling, energy recovery) or landfilled. With this information the researchers assessed the recyclability of each selected vehicle and all vehicles combined, with respect to the parts, components or materials collected for reuse, recycling (including remanufacture) and landfill disposal.

Although ELV recyclability (actual or potential) has been investigated by a number of researchers [Sullivan *et al.*, 1998; Johnson, 2002; Johnson and Wang, 2002; Paul, *et al.*, 2004], the literature does not indicate how much of the parts recovered from ELVs for reuse or remanufacturing are actually directed for reuse or remanufacturing. Just because a part may be recyclable does not mean it is actually recycled. Based on the available literature, there has been no assessment of the actual rates of reuse, remanufacturing, or recycling (independently of shredding) of parts/materials recovered from pre-shredder ELVs on a mass basis (*e.g.,* kilograms of engines reused per tonne of ELVs processed).

Parts removed for potential sale (for reuse or remanufacturing) and not sold in a reasonable amount of time may be shipped with the ELV hulks for shredding [Keoleian *et al.*, 1997]. How much is unsold and ends up being recycled with ELV hulks is not known. Further, available literature does not identify how much of the parts and/or materials recovered from ELVs, if any, is unsold and recycled independently of ELV hulks. Without knowing the quantity of ELV parts and materials actually recovered and sold for reuse, remanufacturing and recycling (prior to shredding), it is difficult to establish how efficient or effective the dismantling process truly is. In general the commercial dismantling process is poorly understood. This notion is compounded by the complexity of the process.

Parts removal strategies/practices used by dismantlers will be driven by a combination of factors. Removal of specific parts and materials is expected to be influenced principally by economic reasons, such as the value and demand for particular automotive parts, and secondly by regulatory requirements, such as the mandatory recovery of vehicle fluids, refrigerants and mercury-containing components. There are also limitations on the space available for parts/material storage through zoning by-law site usage restrictions prohibiting the outdoor storage of parts/materials, and shredder feed stock specifications (*i.e.,* acceptable versus objectionable shredder feed materials).

Large-inventory dismantlers may categorize their inventory by ELV age group: very old vehicles (more than 10 years old); mid-age vehicles (5-10 years old); and very new vehicles (late models less than 5 years old). Very old vehicles would be processed relatively quickly and likely managed as scrap. Mid-age vehicles may be retained for several years and dismantled initially for parts resale and then scrapped. Very new vehicles that come in are typically accident-damaged vehicles written off by insurance companies that may be retained for years, *e.g.,* 5+ years, for parts recovery and resale, or even repaired and sold as a “rebuilt” vehicle.

The large inventories that are maintained by low-volume turnover dismantlers facilitate these businesses to operate what are commonly called "U-Pick-It" yards. These are "self-service" facilities where customers are allowed to come into the storage yard and remove the desired parts from the vehicles themselves.

Based on available literature, ELV dismantling practices generally exclude the removal of plastic components. The research on the economics of automobile dismantling has shown that under current North American market conditions, the disassembly of the non-metallic components, which are predominantly plastics, is generally not economical [Johnson and Wang, 2002]. The research conducted under the Vehicle Recycling Partnership (VRP) identified traditional manual disassembly of non-metal automotive parts to be labor intensive and uneconomical under the current economic conditions of the U.S. recycling infrastructure, even if the value of recyclable non-metallic parts/materials increased [Johnson and Wang, 2002; Spicer *et al.*, 1997]. Without significant advancements in automotive design-for-disassembly or design-for-recycling, manual disassembly may be the only realistic method to recover parts for reuse or remanufacturing. However, the industry may not be limited to the use of traditional manual dismantling methods for recovery of ELV parts and materials for recycling. There may be ways to enhance the traditional dismantling process, such as through alternative materials identification methods, or using intermediate mechanisms or operations to liberate and recover ELV parts/materials after manual dismantling for recycling but prior to sending the ELV hulk to the shredder. Resolving these issues will require understanding what parts/materials are not traditionally dismantled for reuse or recycling as well as the benefits, if any, of increasing the recovery of recyclable ELV parts/materials prior to shredding.

2.3 Shredding Practices

Since the first hammer mill shredder was put into operation in the U.S. in 1962 for processing derelict motor vehicles, shredding has become a widespread method of processing ELVs for metals recovery in North America [Dean *et al.*, 1985]. As of 1995, there were 211 shredding facilities in the U.S. and 20 in Canada, representing 35% of the world's auto shredding capacity [Anon, 1995]. Shredding involves the fragmentation of partially stripped ELVs, as well as other metal-rich scrap materials, followed by separating non-metallic materials from the higher density, metal-rich fraction. The metal-rich fraction is subsequently processed by magnetic separation to separate the ferrous metals (cast iron, carbon steel) from the non-ferrous and non-magnetic metals (aluminum, copper, zinc, nickel, stainless steel, and lead). The low density, non-metallic materials may be further processed, using a variety of separation methods, to improve metal recovery. The non-ferrous metal fraction, commonly referred to by the recycling industry as non-ferrous residue, usually requires additional processing and treatment to separate the materials into individual metal fractions that are of sufficient purity for subsequent recycling by metal refining. The additional processing methods include, for example, screening, eddy current separation, heavy media separation, and air-fluidized sand-bed separation.

Just prior to the introduction of shredding in the early 1960s, baling was the principal method of processing ELVs. Baling involves the compaction of all the materials present in the ELV hulk into a dense cube or "bale" [Bever, 1980; Curlee *et. al.*, 1994]. The resulting baled material, referred to as "No. 2 bundles" [ISRI, 2006], was used without further processing as a, suitable ferrous scrap feed material for "open-hearth" steel production processes. Baling, however, has been largely supplanted by shredding because of:

1) the contaminated, non-homogenous quality of the baled material [Curlee *et al.*, 1994]; and

2) the steel industry's transition starting in the late-50s/early 60s from principally using open-hearth steel making processes to the "basic oxygen furnace" (BOF) process and later, the "electric arc furnace" (EAF) technology [Field and Clark, 1994; Pehlke, 1977].

Cranes or excavators equipped with magnetic lifts or grapples are used to place materials on a shredder's feed conveyor. As previously illustrated in Figure 1, water is customarily added into the shredder to control mill temperature, prevent fires, and help control fugitive air emissions generated by the process. Metals shredding results in significant generation of heat from friction which, if not controlled, can to lead to mill fires, contribute to the generation of oil fumes or mists, and increase the wear on mill parts. The quantity of water that may be applied can vary from minimal quantities - for example just sufficient quantities to keep fires in check, known as "dry shredding" - to flooded conditions, known as "wet shredding". The advantage of wet shredding is that the generation of fugitive air emissions is effectively prevented and the requirement (and cost) for an air emission collection and control system is avoided. The drawbacks of wet shredding are that:

1) the materials discharged from the mill are saturated with water and some sort of system for dewatering the materials and handling the waste water generated by the process is required; and
2) the SR that requires disposal is significantly heavier resulting in higher transportation and disposal costs.

Using a closed-circuit, mill water recirculation system minimizes the requirements for a waste water treatment system.

The air emission control systems used for collection and treatment of fugitive air emissions generated and discharged from a shredder mill typically consist of at least an air cyclone separator for collecting larger particulates, and could include a wet scrubber for removing fine particulates, oil mists/fumes, etc. from the air stream. Although not considered the best available technology (BAT), wet scrubbers are typically used in preference to air filtration systems for treating shredder air emission streams to avoid the risk of fire. Scrubber water is typically collected and recirculated, eliminating the need of waste water treatment and discharge.

The shredded materials discharged from the mill can be processed using a variety of unit operations. Magnetic separation systems (magnetic drum, magnetic head pulley or magnetic belt separators) are used to separate the ferrous metals from the non-ferrous and non-metallic materials. Non-ferrous metals are recovered and concentrated from other non-magnetic materials principally using eddy current rotor separators, commonly in combination with screening devices such as trommel or vibrating deck screens to remove fines [Gesing *et. al.*, 1998; Swartzbaugh *et al.*,1993]. The non-ferrous metal product is commonly referred to in the shredding industry as "non-ferrous residue" and more formally designated "fragmentizer nonferrous mixed metal scrap" (or "Zorba") under the Scrap Specifications Guidelines published by the Institute of Scrap Recycling Industries, Inc. [ISRI, 2006].

Low density, principally non-metallic materials are removed from the heavier, metal-rich materials using air suction. They are then conveyed to air separation devices for recovery, commonly using vertical air classifiers such as Z-box separators and air cyclone separators. Water sprays may be applied within these systems to reduce the potential of fire. Inspection or "picking" stations strategically placed in the shredding process may be used to visually monitor the quality of conveyed materials and/or allow operators to manually remove materials from the flow stream.

2.3.1 Shredder Feed Stream Characteristics

Materials entering the process as shredder feed are not just confined to ELV hulks. Consequently there may be contamination that renders the further use of recovered materials problematic. Based on the literature and the past industrial experiences of the researcher, shredder feed stream materials can include ELV hulks and parts, end-of-life appliances (ELAs), construction and demolition waste, and oversize sheet steel scrap from stamping and punching operations. ELAs, or "white goods", that are commonly directed for shredding are listed below:

- refrigerators
- washers
- dryers
- dishwashers
- air conditioners
- stoves (ranges)
- furnaces
- microwave ovens
- hot water heaters
- freezers
- space heaters
- bath tubs
- dehumidifiers
- range hoods
- sinks

Construction and demolition "waste", in the form of loose miscellaneous metals, will include:

- fluorescent light fixtures;

- building roofing, siding, fascia, guttering, trim, soffits;
- light structural steel components from buildings, bridges, and ship demolition operations; and
- building HVAC components, such as ducting, vents, grilles, fans, and condensers.

Oversize sheet steel scrap from stamping and punching operations, commonly referred to as “offals”, “clippings” or “stampings”, are typically not mixed with other types shredder feed materials and hence, shredded independently of other metals-rich scrap.

The suitability of the shredder feed materials (scrap automobiles, white goods and other metals rich scrap materials) is normally rigidly controlled by a combination of visual inspection and radiation detection of inbound shipments and notification of all scrap suppliers with respect to objectionable objects and materials. Radiation detectors are commonly used on weigh scales for monitoring of inbound and outbound shipments for radioactive materials.

Typically if a prohibited material is detected the shipment may be downgraded (by back charging the material supplier), or rejected and appropriate action taken. These include:

- radioactive materials
- mercury
- lead
- asbestos
- transformers
- gas tanks
- tires
- loose mufflers
- catalytic converters
- unspent air bag canisters
- barrels/drums
- pails or buckets
- compressed gas cylinders
- rags
- PCB materials
- paper and other debris

The quality of the shredder feed material is critical because it will directly influence the quality of the scrap ferrous metals provided to steel mills and iron foundries. It will influence the quality of scrap non-ferrous metals destined for secondary treatment and processing by non-ferrous metal refineries such as aluminum refining. Shredder feed material quality will also influence the quality of shredder residue and consequently, how it may be managed.

2.3.2 Feed Material Quality

There is concern that shredder products - ferrous and non-ferrous metals - and shredder residue (SR), can be contaminated with materials such as PCBs, lead, and cadmium, and potentially become a hazardous material or waste. Shredded ferrous or non-ferrous metal products would be classified as hazardous materials if contaminated with PCB in excess of 50 parts per million [Canada, 1992]. The nonmetallic components of ELVs and scrap appliances (plastics, glass, rubber, paper, textiles, ceramic and paint coatings), as well as a small proportion of non recoverable metals, end up being rejected into the SR waste stream. SR disposal is costly, particularly if it is deemed hazardous due to the presence of sufficient quantities of leachable contaminants, such as mercury (from mercury switches), PCB (from PCB components in white goods commingled with ELVs), or lead (from soldered wire connections).

2.3.2.1 Contaminants in ELVs

Substances in ELVs that may raise some sort of concern, with respect to the environment, health or safety, include lead, mercury, asbestos, cadmium, chromium, and sodium azide (NaN_3). Table 4 summarizes ELV parts and materials where these substances may be found.

2.3.2.2 End-of-Life Appliance (ELA) Composition and Contaminants

Similarly to ELVs, ELAs are composed of ferrous and non-ferrous metals, and non-metallic materials (glass, plastics, paper, etc.); however, there are little data available on the composition of ELAs. One comprehensive study was carried out in 1971 by the National Industrial Pollution Control Council for the U.S. Secretary of Commerce to determine the composition of a selected group of major appliances [Anon, 1971; MOE, 1991]. Table 5 summarizes the amounts of different materials found in six types of the household appliances studied. At that time major appliances weighed approximately 90 kg. Steel is the primary recyclable material in appliances.

As shown in Table 5, air conditioners are approximately 50 percent by weight ferrous material and all other listed appliances are composed of between 80 and 90 percent ferrous material. The ferrous portion of appliances is in four forms: painted and porcelain coated steel, uncoated steel, stainless steel, cast iron [MOE, 1991]. About 90 percent of the total ferrous metal content of appliances is coated steel [MOE, 1991].

The non-ferrous contents of the appliances, with the exception of air conditioners, average approximately 5 percent by weight with 2 percent as copper components and 3 percent as aluminum components. Air conditioners on the other hand contain approximately 30 percent copper and 8 percent aluminum components.

Table 4 Contaminants found in ELV parts and materials

Contaminant	Presence in ELV Parts and/or Materials	Resource
Lead	Batteries (representing 90-95 % of total lead used in vehicles)	EU, 2002; Sander *et al.*, 2000; Westerlund, 2001.
	Brake pad linings	
	Vibration dampeners	
	Fuel hoses	
	Soldering	
	Wheel balance weights	
	Alloying element or impurity in steel, zinc coatings, lead-bronze bearing shells and bushings, aluminum and copper alloys used in vehicles	
	Stabilizer in plastics such as polyvinyl chloride (PVC);	
	Impurity/component in glass and ceramic matrices in electronic parts;	
	Piston coatings and spark plugs	
	Used oil, through corrosion and wear of alloys contained in vehicles and as a result of impurities in the zinc used to provide wear protection to the engine	Davis *et al.*, 2001; Sorme and Lagerkvist, 2002
Mercury	Tilt switches on hood and trunk lighting assemblies; switches on some 4-wheel drive ABS applications.	Huber, 1997
	High Intensity Discharge (HID) head lights and tail lights	
	Fluorescent lamps used in Virtual Image Instrument Panels	
Asbestos	Brake pads	
Cadmium	Brake pads	EU, 2002; Gerrard, 2005; Scheirs, 2003; Westerlund, 2001
	Tires, as a contaminant in the zinc oxide used in the rubber, however, tire wear releases of cadmium to the environment are very small	
	Plastic, as a pigment;	
	PVC, as a stabilizer;	
	Thick film pastes used in electronic circuit boards	
	Used oil, through corrosion and wear of alloys contained in vehicles and as a result of impurities in the zinc used to provide wear protection to the engine; quantities emitted in this manner are negligible	Davis *et al.*, 2001; Gerrard, 2005; Sorme and Lagerkvist, 2002
Chromium	Corrosion resistant coatings	
Sodium azide (NaN_3)	In air bag inflation systems, sodium azide (NaN_3) is reacted with potassium nitrate (KNO_3) to produce nitrogen gas	

As previously illustrated in Figure 2, automotive manufacturers have been reducing the ferrous metal content of automobiles and increasing the non-ferrous metal and plastic content. Similarly, appliance manufacturers have been increasing the use of lighter plastics in appliances in place of steel [Cosper *et al.*, 1993]. This trend is demonstrated in Table 6. The weights of white goods have been reduced significantly over the 20-year period, particularly refrigerators, freezers and automatic washers [AHAM, 1993; Cosper *et al.*, 1993].

Table 5 Materials Used In Selected Major Appliances
[Anon, 1971; adapted from MOE, 1991]

Material	Appliance											
	Air Conditioner		Kitchen Range		Refrigerator		Dishwasher		Washer		Dryer	
	(kg)	(%)	(kg)	(%)	(kg)	(%)	(kg)	(%)	(kg)	(%)	(kg)	(%)
Steel	28.1	49.6	80.8	89.0	117.9	79.9	54.4	81.7	93.9	82.8	60.3	91.8
Copper & Alloys	16.3	28.8	0.9	1.0	5.4	3.7	2.3	3.5	1.8	1.6	0.9	1.4
Aluminum & Alloys	4.5	8.0	0.9	1.0	4.1	2.8	0.9	1.4	6.8	6.0	1.8	2.7
Zinc	0.0	0.0	0.9	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Metals	48.9	86.4	83.5	92.1	127.4	86.5	57.6	86.5	102.5	90.4	62.6	95.3
Glass	0.0	0.0	5.4	6.0	4.5	3.1	0.0	0.0	0.1	0.1	0.1	0.1
Polymer	4.1	7.2	0.9	1.0	15.4	10.5	9.0	13.5	3.2	2.8	2.7	4.1
Paper	3.6	6.4	0.9	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Concrete	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9	2.6	0.0	0.0
Other Non-Metallic Inorganics	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.6	4.1	0.0	0.0
Total Non-Metals	7.7	13.6	7.2	8.0	19.9	13.6	9.0	13.5	10.8	9.6	2.8	4.2
Total	56.6	100.0	90.7	100.0	147.3	100.0	66.6	100.0	113.4	100.0	65.7	100.0

Table 6 Changes in Appliance Weights Over Time [AHAM, 1993; Cosper *et al.*, 1993]

Appliance Type		Weight (lbs)				
		1961	1972	1977	1982	1992
Laundry	wringer washer	135-140	n/a	130-135	n/a	n/a
	automatic washer	225-250	n/a	205-225	n/a	150-170
	washer/dryer	320-340	n/a	n/a	n/a	n/a
	dryer	155-195	n/a	140-160	n/a	120-150
Dishwashers	portable	n/a	160-180	n/a	150-170	150-170
	built-in	n/a	110-130	n/a	100-110	90-100
Refrigerators	top mount: 20 ft^3	n/a	335-355	n/a	250-265	230-240
Freezers	chest: 25-30 ft^3	n/a	335-355	n/a	270-290	240-260
Microwave Ovens	full size: 1.4-1.6 ft^3	n/a	n/a	n/a	65-85	45-65
Room Air Conditioners	10,000 BTU standard	n/a	140-160	n/a	150-160	115-125
	compact	n/a	110-120	n/a	100-115	85-95
Ranges	30 inch standard	n/a	175-185	n/a	165-175	170-180

Plastics in appliances have better insulating properties, improve energy efficiency, and lower the manufacturing and transportation costs. On the other hand, an appliance built today contains less scrap value than one manufactured 30 years ago.

As with ELVs, ELAs are potential sources of contaminants, such as PCB, cadmium, lead and mercury. Table 7 summarizes typical uses of lead, cadmium and mercury in ELAs. The potential for PCB contamination of shredder products and residues is of particular concern. PCBs are a group of synthetic compounds which were widely used in Canada and the U.S. in transformers and capacitors as dielectric fluids until the late 1970s.

The manufacturing and use of PCBs in electrical components was, for the most part, banned by the United States Environmental Protection Agency in 1979 [Cosper *et. al.*, 1993] and banned in Canada under CEPA on July 1, 1980 [CCME, 1989; Canada, 1991]. Some exemptions allowed manufacturers to phase out existing inventories and production during the early 1980s [Apotheker, 1989]. Now capacitors and fluorescent light ballasts manufactured since the prohibition of PCBs are required to be clearly identified as containing no PCBs. In appliances PCBs may be found in oil-filled running capacitors [Apotheker, 1989; Krambeck and Morris, 1990] or in the capacitors and the tar potting materials found in fluorescent light ballasts [Day, 1995a; McDonald and Tourangeau, 1986].

Table 7 Lead, cadmium and mercury contaminants found in ELA parts and materials

Contaminant	Presence in ELA Parts and/or Materials	Resource
Lead	Solder on electrical wires and refrigeration heat exchangers	EU, 2002; Sander *et al.*, 2000
	Trace quantities in some paints and coatings	
	Trace quantities in steel as an alloying element	
	Plastics (such as PVC) as a stabilizer	
Cadmium	Trace quantities in solder, porcelain enamel and galvanized steel	MOE, 1991
	Plastics, as a pigment	EU, 2002; Scheirs, 2003
	PVC, as a stabilizer	
Mercury	Fluorescent lighting used to back-light control panels on ranges and clothes washers	AHAM, 2005; Cosper *et al.*, 1993
	Safety devices in pilot-light equipped, natural gas stoves and water heaters, where by a mercury switch is used to shut-off gas flow to the burner when the pilot-light is not burning;	AHAM, 2005, Cosper *et al.*, 1993
	Internal lid light switch of some chest freezers produced before 2000	AHAM, 2005
	Tilt switches in some washing machines manufactured before 1972	

Although it has been more than 23 years since the use of PCBs was banned and despite capacitor recovery programs implemented to divert PCB-containing materials from shredder feed streams [Sawyer-Beaulieu, 1995], the potential presence of PCB components in scrap white goods continues to raise significant concerns for scrap processors that shred white goods. Even after 23 years, there is still the evidence of PCB occurrence in shredder products and residues. For example, Table 8 summarizes PCB concentrations in SR samples reviewed in published literature. It is unclear why PCBs are still present in SR and whether past cases of contamination are isolated cases. Furthermore, contaminants such as PCBs may create a barrier to the full potential reuse or recycling of SR or its individual constituents.

2.3.2.3 Contaminants in Demolition Waste and Other Feed Materials

There may be the potential of contaminants in demolition waste, such PCB, lead and mercury, particularly if potentially hazardous materials are not effectively isolated and removed before demolition of old buildings or other infrastructure. PCBs may be present, for example, in older fluorescent lighting ballasts. Mercury may be present in the tilt switches used in mechanical thermostats.

Lead may be present in the paint used on structural steel of commercial and industrial buildings or structures. The manufacture and use of lead-based paint for residential applications has been prohibited since 1978 in the U.S. and 1980 in Canada. The use of lead-based paint for industrial and commercial applications, however, is not restricted [Canada 1995; SPSTI, 2004; USEPA, 1995]. Since the early 1950's, lead compounds have been used as effective corrosion inhibitors and pigments in coatings on steel structures [USEPA, 1995]. Lead-based corrosion-resistant paints may be found on scrap steel recovered from demolition of commercial and industrial building, bridges, and ships [SPSTI, 2004; USEPA, 2000].

Table 8 Summary of PCB Concentrations in Various Shredder Residue Samples

Approx. Time of Study	Source of Sample	Input Type	Sample type	Shredder Residue PCB Concentration (mg/kg)		Resource
1988 to 1991	28 samples from 7 U.S. sites	ELVs		32		USEPA, 1991
	15 samples from 5 U.S. sites	White Goods		80		
	9 samples from 3 U.S. sites	Mixed Inputs*		180		
1994 to 1995	D&J Wendt Corporation, Tonawanda, N.Y.		Cyclone Fluff (ASR-2)	66.2		Sendijaredvic *et al.*, 1995
	David J. Joseph Company, Cincinnati, Ohio		Flotation Fluff (ASR-5)	11.1		
	Huron Valley Steel Corporation		Dense Shredder Residue (ASR-4)	5.9		
	Huron Valley Steel Corporation		Cyclone Fluff Fines (ASR-7)	5.7		
1998 to 2000	Facility (P1) in Sweden	ELVs	P1 half dism.	6.7	--	Börjeson *et al.*, 2000
		ELVs	P1 full dism.	6.1	--	
		ELVs	P1 mixed cars	1.1	41	
		Mixed Inputs	P1 mixed waste	12	77	
		White Goods	P1 white goods	34	114	
		Industrial Waste	P1 industrial waste	24	62	
	Facility (P2) in Sweden	ELVs	P2 half dism.	2.1	--	
		ELVs	P2 half dism.	0.5	--	
		ELVs	P2 full dism.	0.6	--	
		ELVs	P2 mixed cars	1.5	14	
		Mixed Inputs	P2 mixed waste	39	217	
		White Goods	P2 white goods	102	254	
		Industrial Waste	P2 industrial waste	25	295	
2003 to 2004	U.S.		Fines	3.08		Winslow *et al.*, 2004
			Dirty Foam	3.73		
			Dirty Plastics	0.98		
	Swiss		Fines	2.8		
			Dirty Foam	1.77		
			Dirty Plastics	0.37		
	German		Fines	10.7		
			Dirty Foam	6.99		
			Dirty Plastics	0.54		

* includes ELVs, whitegoods, demolition materials, etc.

2.3.2.4 Shredder Residue

As previously mentioned the ELV dismantling and shredding practices currently used in the U.S. and Canada results in approximately 5.6 M metric tonnes of SR – including in excess of 1.9 M metric tonnes of plastic – that is mostly landfilled.

Shredder residue reuse and recycling mechanisms have been generally limited to proposed, experimental or conditional applications, such as:

- reuse as landfill day cover [Cirko, 2000; Day, 1995b];
- reuse of the organic portion of SR (after it has been upgraded) as an alternative fuel source or reducing agent in blast furnaces [Cirko, 2000; Takaoka *et al.*, 2003];
- recycle SR in the manufacture of composite plastic products, *e.g.*, plastic lumber [Lazareck, 2004];
- pyrolysis of SR to produce a synthetic coal product [Day *et al.*, 1994; Jones, 1994; Day *et al.*, 1999];
- tertiary recycling of SR plastics, involving the conversion of the plastics into low-molecular weight hydrocarbons, such as via low-temperature, catalytic conversion for reuse as chemicals or fuels [Allred and Busselle, 2000];
- reuse SR as a hydroponic garden growing medium [Mattes, 1996].

In addition, various research groups are developing processes for separating mixed plastics typically found in SR into the individual types of plastics using gravity separation, froth flotation, air classification, electrostatic separation, etc. [Jody *et al.*, 1996; Winslow *et al.*, 2004; Brown, 2000].

Although the above alternatives may be viable and seen as environmentally beneficial ways of reusing or recycling SR, they may be inefficient or less effective than anticipated. Energy and resources are necessary both to shred the materials, as well as to then further separate out individual materials for recycling or other uses, which themselves consume non-renewable resources in secondary processes.

Developing and implementing technologies for the recovery of ELV plastics prior to shredding could be simpler and of greater benefit than developing post-shredder ELV plastics recovery technologies. If such mechanisms can be identified and developed for the recovery of automotive plastics, particularly thermoplastics, from pre-shredder ELVs, they could lead to the recovery and recycling of some of the estimated 1.9 million metric tonnes of plastics being disposed of in Canada and the U.S. annually. Plastics comprise roughly one third of the approximate 5.6 million tonnes of SR disposed of annually in landfills, representing a loss of a valuable non-renewable resource. Based on conservative market values of $2.00 U.S./kg and $0.75 U.S./kg for virgin plastic resin and recycled plastic, respectively, recovering and recycling (instead of disposing) 1.9 M tonnes of plastic represents a potential savings in excess of $2.3 B U.S. annually (at $1.25 U.S./kg of plastic recovered).

By using an LCA approach, alternative "dismantling methods" may be identified for recovering ELV parts/materials for recycling prior to shredding. For example, rather than shredding the entire hulk with minimal prior hand disassembly, intermediate or limited comminution processes may be able to liberate additional items, which then may be processed by secondary or even tertiary processes. Thus, the emphasis may not lie with a single, all inclusive unit operation, but with the creative use of multiple operations to remove potential recyclables, not unlike those used in processing municipal solid waste. Furthermore, preliminary research conducted by Tam and Jekel [2004] suggests that different degrees of material liberation may be achieved depending on the mechanism used for fastening materials together (*e.g.*, rivets versus adhesives). The ability to recover and recycle constituent materials in an ELV, for example, may be improved by choosing a fastening method during the design stage, such as riveting compared to gluing, and then a subsequent complementary recovery process that promotes liberation.

The research undertaken and described herein demonstrates how LCA methods may be applied to a product's end-of-life phase, starting with construction of the LCI, to better understand the environmental burdens associated with end-of-life processes. By using the LCA approach, this research identifies the efficiencies of the dismantling process in terms of the mass flows of parts (by part type) directed for reuse, remanufacture and pre-shredder recycling. The dismantling process inefficiencies are identified by the mass flow of leftover ELV hulks and parts directed for shredding. The parts and materials not recovered by the dismantler and directed for reuse, remanufacture and pre-shredder recycling may represent missed opportunities for recovery of materials for pre-shredder recycling.

Using the parts mass flows ascertained in this research and the material compositions of these parts (refer to Section 3.2 Parts Mass Study) in conjunction with assessing parts recovery methodologies, dismantling procedures, and workflow, it is expected that the potential opportunities for enhanced materials recovery for "post-dismantling/pre-shredder" recycling can be identified. Increasing the recovery of materials - particularly plastics - for "post-dismantling/pre-shredder" recycling could stimulate increased economic returns to the ELV dismantling and shredding industry by generating more recyclable products and reducing the amount of material disposed of as shredder residue.

2.4 Regulation of ELV Management

Although the ELV management industry is well established in North America and the processing technologies are generally understood, the specifics about each stage or unit operation of the ELV management process are not well documented. Included are the regulatory aspects of the ELV management system. ELV dismantling and shredding facilities both have their share of regulatory issues that must be addressed. These issues may include:

- environmental site development licensing;
- facility/business operations licensing;
- business-related or operations-related compliance documentation and reporting;
- zoning bylaws restricting site use;
- air emission control and permitting;
- waste water management, control and permitting;
- storm water management, control and permitting;
- waste management systems permitting;
- environmental performance/compliance reporting.

The "regulatory" mechanisms applied include involuntary (*e.g.*, legislated acts, regulations, bylaws) and voluntary mechanisms (*e.g.*, best management practices or BMPs). The regulation of the ELV management process is primarily focused on business and operating practices as opposed to the regulation of the retired vehicles themselves. The operations, activities and practices that are typically regulated or controlled in facilities that are in the business of managing ELVs include:

- emission of air contaminants;
- discharge of waste water (process and/or storm water);
- generation and disposal of wastes;
- site use and materials storage.

In addition, these facilities typically require business licensing (under provincial/state legislation and/or municipal bylaws), which permits them to carry out dismantling and recycling of ELVs. Municipal bylaws governing the licensing of ELV dismantling and recycling commonly stipulate site-use conditions or restrictions such as materials storage restrictions or site accessibility conditions. Sawyer-Beaulieu and Tam (2006) discussed these aspects extensively and focused on the regulation of the first stage in the ELV management process – vehicle retirement.

According to available literature, British Columbia is the only jurisdiction in Canada and the U.S. having ELV management legislation. British Columbia's Vehicle Dismantling and Recycling Industry Environmental Planning Regulation requires a dismantler processing 5 or more ELVs per calendar year to establish, register, follow and maintain an environmental management plan (EMP) for the ELVs they process [British Columbia, 2007]. The EMP must describe how prescribed wastes (liquids, refrigerants, batteries, mercury switches and tires) are removed, stored, treated, recycled and/or disposed. It must also define management processes for minimizing or eliminating the discharge of waste to the environment [British Columbia, 2007].

2.5 Applying LCA

Life-cycle assessment (LCA) examines, identifies, and evaluates the relevant environmental implications of a material, process, product or system either across its life span from creation to disposal or to its recreation in the same or another useful form [Graedel and Allenby, 2003]. The potential of LCA as a useful decision making tool in the design of automotive materials, processes and products has been demonstrated. Life-cycle analysis, in combination with economic assessment mechanisms, allows designers, engineers and decision makers, to make better, more informed decisions at a very early stage of the design [Gediga *et al.*, 1998]. LCA principles have been used to evaluate the environmental and economic burdens associated with the design and manufacture of automotive paints [Papasavva *et al.*, *2001*], vehicle instrument panels [Gediga *et al.*, 1998], fenders [Harsch *et al.*, 1996], air intake manifolds [Keoleian and Kar, 2003] and fuel tank systems [Keoleian *et al.*, 1998]. LCA has been used to investigate the environmental and economic benefits of using remanufactured engines versus brand new engines [Smith and Keoleian, 2004] and alternative automobile/fuel combinations [MacLean and Lave, 2003].

In these investigations, typical life cycle inventories (LCI) and life cycle impact analyses (LCIA) were performed to evaluate the environmental benefits and drawbacks of the different product or system designs used. The environmental burdens were identified, for the most part, based on energy and resource consumption, contaminants emitted to air (principally "greenhouse gases"), contaminants discharged to water and wastes generated, for the phases of material extraction and production, product manufacturing, product use, and end of life. By comparing the environmental burdens posed by various alternatives, one product or system design, or a specific aspect of the design, could be identified to be environmentally and/or economically favored over another design (or design aspect). For example Smith and Keoleian [2004] used LCA modeling to demonstrate that the remanufacture of a midsize automotive gasoline engine in the United States, versus the manufacture of a brand new engine, could be accomplished using 68% to 83% less energy, 26% to 90% less raw materials and generating 65% to 88% less solid waste. Further the remanufacture of an engine versus manufacture would produce between 48% to 88% less carbon dioxide, nitrogen oxide and carbon monoxide emissions (all greenhouse gases), as well as 71% to 84% less sulfur oxide emissions.

LCA has been touted to be a valuable tool for product (or system) design improvement. The literature clearly documents the potential benefits of using LCA in product and system design applications; however, there is relatively little evidence of actual product design improvements implemented as the direct result of LCA investigations.

2.6 Overview of Issues Behind LCA Use

There are several issues that can complicate the use of LCAs and reduce their effectiveness, regardless of the subject to which they are applied. These issues include metrics and indicators, applicability of data, and uncertainties behind missing or surrogate data.

The environmental criteria and boundaries commonly used in LCIs and LCIAs are global in nature, far reaching, not directly tangible, and cumbersome to use when compared to decision-making criteria used by designers, engineers or manufacturers on a daily or localized basis. Some of the more common environmental criteria or metrics encountered in typical LCAs to measure environmental performance include the large scale, intercontinental, intracontinental or global criteria listed below:

- resource use (renewable and non-renewable): energy, mineral, land and water resources [Teulon, 1997; Harsch *et al.*, 1996];
- global warming from green house gas (GHG) emissions: carbon dioxide; carbon monoxide; nitrous oxide; nitrogen oxides; etc. [Teulon, 1997];
- atmospheric ozone depletion; and

- atmospheric and aquatic acidification [Teulon, 1997].

Other metrics that may be used, but encountered less frequently in traditional LCAs, are the small scale, regional or local criteria [Harsch *et al.*, 1996]. These may include:

- solid and hazardous waste generation and disposal;
- eutrophication;
- photochemical ozone generation;
- noise;
- vibration;
- odor;
- air contaminant emissions: suspended particulate matter (TSP, PM_{10}, $PM_{2.5}$), volatile organic compounds (VOCs), etc.;
- contaminants discharged to water;
- human health effects; and
- energy use inefficiencies/losses, *e.g.*, building HVAC and process heating & cooling.

Traditional LCAs that employ the more common large scale metrics may be used by designers, engineers and manufacturers as a tool to realize long-term environmental benefits as a consequence of an LCA-based design change (material, process, or system). Further, traditional LCAs may provide regulators with an invaluable tool to evaluate the long-term effects (benefits and drawbacks) that proposed new environmental legislation may have on an industry prior to its promulgation.

However, it may be difficult for engineers, designers or manufacturers to justify, let alone implement, manufacturing or design changes in real-time based on evaluations that deal with long term, global burdens. The environmental benefits that may be achieved from an LCA-based design change are expected to be realized over a relatively long-term period of time, and are not likely to be perceived over a short-term period. For example, a design change in the automotive industry, from conception to manufacture to the time the product reaches the market place, can take several years to implement, while environmental benefits may take decades to realize.

Another limitation of typical LCA is that the systems or processes (material processing, material manufacturing, etc.) are typically modeled as "black boxes". This model offers little or no insight as to what transpires inside the box, and as a consequence, provides little or no confidence that the inputs and outputs are truly applicable to the situation.

In the event that the actual data for a case or site specific situation is not available, the environmental criteria used in an LCA may be from generic or secondary/surrogate sources. For example, Keoleian and Kar [2003] estimate air contaminant emissions resulting from the manufacture of different North American air intake manifold designs using air emissions from European sources. Under these circumstances, the applicability of the data may be justifiably challenged.

"Generic" or "typical data" are data that are not necessarily specific to the industry or process being studied, but considered generally applicable and usually come from a variety of literature sources and databases [Tam and Abdulrahem, 2005]. "Surrogate data" are data that come from an actual facility or process that appears to be similar or identical to the one being studied and are assumed to be applicable, even if the degree of applicability of such data to the specific facility or process cannot be confirmed [Tam and Abdulrahem, 2005]. The diversity of the generic- and surrogate-source data used in an LCA application can affect the significance, dependability, and confidence of the LCA results, as well as influence the interpretation of the study outcome [Fava, *et. al.*, 1994; Fleischer *et. al.*, 2003; Krozer and Vis.,1998; Weidema and Wesnaes, 1996].

Tam and Abdulrahem [2005], for example, performed a case study, using the automotive "body-in-white" painting pretreatment process, to determine if a life cycle inventory developed using "conceptual data" is comparable to a life cycle inventory (LCI) prepared using process or site-specific data. Site specific data representing the painting pretreatment process of Facility A was compared to conceptual data representing the pretreatment process Facility B. The "conceptual data", as defined by the researchers, was a combination of surrogate data with some generic data added to fill in data gaps. The analysis was based on comparing rates of chemical usage and rates of heavy metal discharge as solid waste:

1) The consumptions of five types of chemical products used in the pretreatment process, *i.e.*, chemical cleaner, replenisher, conditioner, liquid additive and chemical controller, were compared in terms of g/vehicle processed and g/m^2 of painted surface.

2) The quantities of reportable heavy metals discharged as solid waste from the two facilities were assessed, normalized first to a per vehicle basis and then expressed in g/vehicle processed and g/m^2 of painted surface.

Comparing the results from the conceptual data-based LCI versus the site-specific data-derived LCI revealed significant differences throughout the inventories; there were differences in the quantities of chemical products used in the pretreatment processes, as well as variations in the reported results depending on the functional unit used (g/vehicle versus g/m^2) [Tam and Abdulrahem, 2005]. In terms of the differences between the two sets of data - site specific versus conceptual - chemical product usages (in g/vehicle) differed by as little as 5% to up to 99%. When heavy metal discharge rates were compared for the two facilities, the differences in solid waste metals discharged varied significantly depending on how they were expressed (as g/vehicle or g/m^2). For example, when expressed in g/vehicle, manganese and manganese compounds in the solid wastes of Facility A were approximately 29% greater than in the solid wastes of Facility B. In contrast, when expressed on a per unit area basis (g/m^2) the manganese related solid wastes from Facility A were less than those from Facility B [Tam and Abdulrahem, 2005]. It would be difficult for an LCI practitioner to discern which results should be considered to be the more representative of the situation if he or she was unfamiliar with the source or quality of the data used in the LCI. It leaves the analysis open to questionable interpretation.

Considering the shortcomings of traditional LCA practices, as highlighted above, LCA methods should be applied alternatively on a smaller, "real-time" scale, *i.e.*, on sub-processes or unit operations. This would provide designers, engineers and manufacturers the opportunity to identify and understand the environmental ramifications of what goes on inside the traditional LCA “black box”.

2.7 LCAs Applied to Vehicle End-of-Life (VEOL)

Within the automotive industry, LCA has been used customarily to study the environmental and economic burdens associated with the design, manufacture and use of different automotive parts, components or systems. LCA has also been used to assess the burdens associated with the total vehicle life from cradle-to-grave, starting with raw materials production, and then extending to vehicle manufacturing, vehicle use, and vehicle end-of-life. The application of the LCA process to the VEOL phase, however, has generally been incomplete.

Based on the available literature, the VEOL phase may be treated as a simple black box model encompassing the dismantling and shredding processes, with the inputs and outputs of the box limited to or focused on:

- the energy consumed during vehicle dismantling and/or shedding;
- the shredded ferrous and non-ferrous metal products recovered for recycling; and
- the shredder residue that is generated and destined for treatment and/or disposal [Funazakia *et. al.*, 2003; Keoleian *et. al.*, 1997; Staudinger and Keoleian, 2001].

Other inputs and outputs of the VEOL phase - water usage, parts and/or materials recovered during dismantling for reuse, remanufacturing and recycling, waste water discharges, air emission discharges (point source and fugitive) – are often scoped out of the analysis [Funazakia *et. al.*, 2003], assumed not to be applicable [Sullivan *et. al.*, 1998], or simply left unaccounted for because the information is just not available [Funazakia *et. al.*, 2003; Keoleian *et. al.*, 1997].

Some life cycle analyses of VEOL phases have been performed using surrogate and/or generic data [Cobas-Flores *et. al.*, 1998; Sullivan *et. al.*, 1998] but not site- or process-specific data, and generally have been used to predict potential outcomes, such as the impacts on stakeholders at the end-of-life phase, if:

- the recovery of plastics from ELVs increases; or
- the use of light-weight materials in vehicles increases [Cobas-Flores *et. al.*, 1998].

Cobas-Flores *et. al.* [1998] analyzed different postulated scenarios of vehicle end-of-life trends in the United States using the Vehicle End of Life Computational (VEOL) Model developed by the Vehicle Recycling Partnership (VRP), a consortium of Chrysler Corporation, Ford Motor Company and General Motors. The VEOL computer model uses the twenty-four different material types and twenty-six different automotive parts and assemblies, summarized in Table 9, to represent cars and light-duty trucks [Bustani *et. al.*, 1998]:

Table 9 Material types and automotive parts and assemblies used in the VEOL computer model [Bustani *et. al.*, 1998]

<u>VEOL Modeled Parts and Assemblies</u>

1. Base Engine
2. Body Shell
3. Cowl, Wipers
4. Engine Compartment
5. Fluids
6. Front/Rear Bumper & Grille
7. Front/Rear Door & Liftgate
8. Front Fenders
9. Front/Rear Seats
10. Front Suspension
11. Fuel Tank
12. Head-Lights/Tail-Lights
13. Heater/Ventilation
14. Hood
15. Instrument Panel/Center Console
16. Interior/Exterior Trim & Carpet Floor Mat
17. Rear Suspension
18. Roof
19. Safety Systems
20. Side Glass
21. Transfer Case
22. Transmission
23. Tires

24 Wheels

25. Windshield/Rear Window
26. Others

<u>VEOL Modeled Material Types</u>

Plastics

1. Acrylonitrile-Butadiene-Styrene (ABS)
2. Polyamide [Nylon] (PA)
3. Polyester-Polyethylene terephthalate (PET)
4. Polycarbonate plastics (PC)
5. Polyurethane (PUR)
6. Polypropylene (PP)
7. Polyethylene (PE)
8. Poly vinyl chloride (PVC)
9. Polyolefinic [TPO] (TEO)
10. Other plastics (OP)

Ferrous

11. Carbon Steel (CS)
12. Iron (Fe)

Non-ferrous

13. Aluminum (Al)
14. Copper & Brass (Cu)
15. Zinc (Zn)
16. Magnesium (Mg)
17. Lead (Pb)
18. Stainless Steel (SS)
19. Other non-ferrous (ONF)

Other materials

20. Glass (GL)
21. Tires Rubber (TR)
22. Other Rubber (OR)
23. Fluids (FL)
24. Other materials (OM)

These materials and assemblies were selected in consultation with industry experts to estimate the composition of typical cars and light duty trucks. The VEOL computer model could then be used to predict and study, for example, the potential impacts of changes in the weight content of the 24 different materials on the total weight of the cars and light trucks [Bustani *et. al.*, 1998]. However, the VEOL modeled materials and assemblies are not necessarily representative of the specific parts, components and subassemblies in actual vehicles, nor of the actual quantities of parts recovered by dismantlers for reuse or remanufacturing. A part or assemblage of parts recovered by a dismantler may be considerably different than the parts configurations in the VEOL model as a consequence of:

1) how the parts are physically removed from a vehicle;
2) what parts are in demand; and
3) what parts are considered to have recovery value.

Item (1) above requires more explanation. If an approach such as the VEOL modeled parts is used, the analyst would believe and likely conclude that parts or assemblages (a defined group of parts, such as a car dashboard) can be both assembled and removed in nearly the same manner. This would be mean that all or nearly all the parts would be available for reuse, resale and recovery, and any LCA analysis would likely reflect this availability. In reality, dismantlers will often employ mechanized, semi-destructive dismantling techniques such as cutting, in which parts of negligible or lower value will be sacrificed to permit access to high value parts or assemblages. Sacrificed parts would not be available for reuse or resale, and might not even be recovered for materials recycling if the effort to set such materials aside cannot be economically justified by the dismantler.

Sullivan *et. al.*, [1998] discuss the LCI prepared by the United States Automotive Materials Partnership Life Cycle Assessment Special Topics Group (USAMP/LCA) to benchmark the environmental performance of a generic vehicle. As previously mentioned under Section 2.1, the generic vehicle is a synthesis of three 1995 vehicles, a Dodge Intrepid, Chevrolet Lumina and Ford Taurus. The LCI is based on "generic" materials, parts, components, and sub-assemblies created from these three vehicle types, and hence, are not necessarily representative of part types, and quantities, that will be typically managed by full-scale dismantling operations. In addition, the USAMP/LCA LCI is based on the assumption that replacement parts included in the use phase of the generic vehicle are original OEM parts and not remanufactured or reused parts [Sullivan *et. al.*, 1998].

According to available literature, there has not been a gate-to-gate LCI completed for North American dismantling and shredding processes using site-specific data, and LCAs conducted to date rely significantly on assumed values and extrapolations within models.

2.8 The Potential Benefits of Applying LCAs to ELV Processes

Given the types of problems encountered with ELV processes as mentioned in this chapter, LCA should prove to be a useful method of improving the understanding and resolution of ELV management problems for several reasons:

1) Even though recovery and recycling operations are geared towards materials recovery, they are not "burden free". They consume resources and produce emissions. As opposed to the more traditional assessment of these burdens relative to regulatory compliance limits or guidelines, or relative to economic performance, LCA can be used to identify and assess EOL burdens and compare them to burdens due to other life cycle phases to establish the level of significance or insignificance over the total vehicle life.

2) LCAs offer a much broader perspective on material and energy inputs and outputs and are not limited to traditional definitions. As opposed to evaluating energy inputs in simple engineering units, *e.g.*, as in kilowatt-hours (kwh), alternative functional units may be used, such as kwh per tonne of vehicles processed at EOL.

3) LCAs are concerned with issues that are less defined than conventional means of design analysis, (*e.g.*, cost benefit analysis), but are still important to current society. Typically, such issues revolve around environmental or sustainability efforts. However, LCA can be used to see how product impacts are influenced by consumer perceptions. For example, LCA may be used to understand how perceptions of quality about re-used and remanufactured parts influence the success or failure of reuse and resale initiatives.

3 RESEARCH METHODOLOGY

The vehicle end-of-life (VEOL) dismantling and shredding process can be improved to yield greater and more usable quantities of recovered materials. Furthermore, dismantling and shredding have been long viewed as separate processes that just happen to follow sequentially. An improved understanding of their relationship could increase the effectiveness of dismantling and shredding as an overall process. There may also be ways to enhance the traditional dismantling process, such as through alternative materials identification methods, or using intermediate mechanisms or operations to liberate and recover ELV parts/materials after manual dismantling for recycling but prior to sending the ELV hulk to the shredder.

A thorough LCA of this VEOL process should yield valuable insights into the consequences of the current recovery infrastructure and what alternatives could be implemented. This research undertakes a gate-to-gate life cycle inventory of the VEOL dismantling and shredding process, the first step of conducting a life cycle assessment of this system.

Figure 4 schematically illustrates the general outline of the research methodology. Through literature review and networking with industry and government representatives, viable case study opportunities were established with working dismantlers and shredding operations. Literature reviews identified past and present ELV practices, unit operations, and/or technologies, and their practical constraints and issues of concern.

Through the networking efforts with representatives from industry trade associations, such as Automotive Recyclers of Canada (ARC) and Canadian Association of Recycling Industries (CARI), case studies were established with seven Canadian ELV dismantling facilities and one shredding operation. The case studies, which included site visits of all eight facilities, permitted:

1) identification of practices or unit operations used by the dismantling facilities and those used in the shredding operation;
2) recognition of relationships between dismantling and shredding operations; and
3) understanding the conventional terminology common to the dismantling and shredding processes.

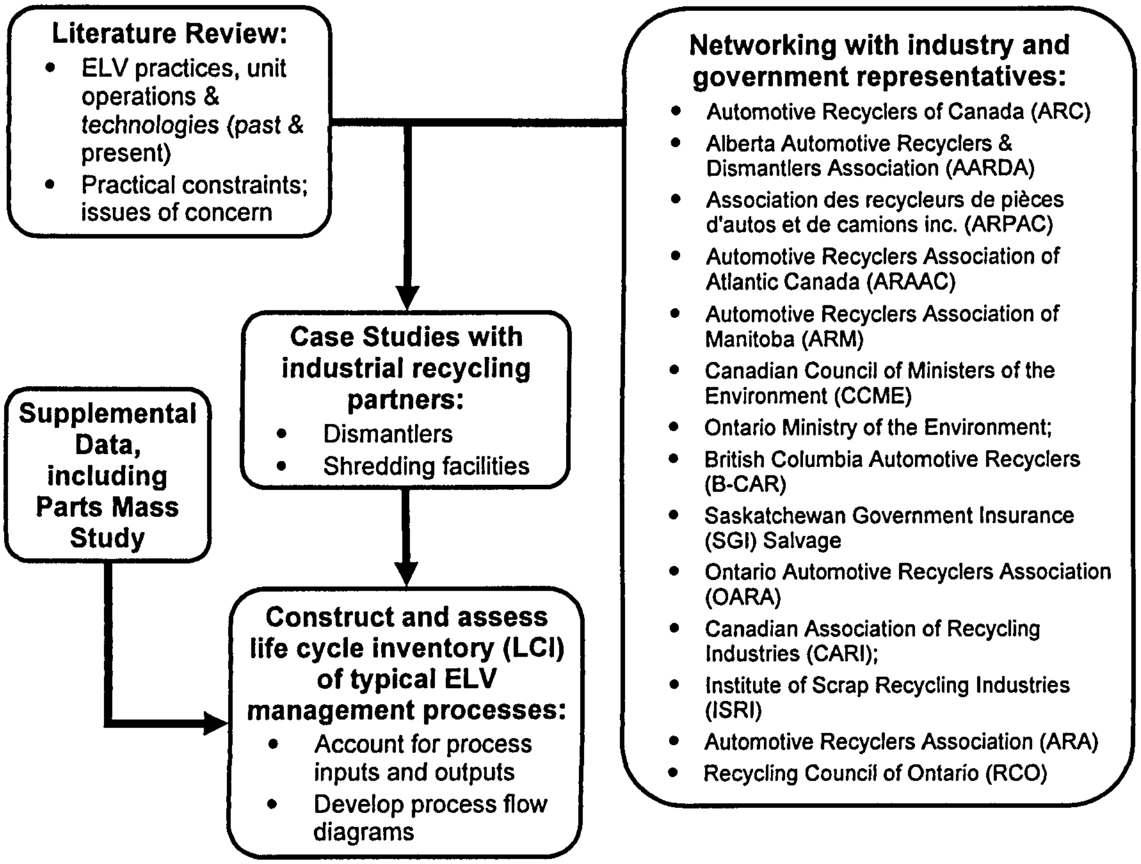


Figure 4 Schematic diagram of research methodology.

Based on information acquired during the site visits, as well as the researcher's extensive professional work experience in the metals recycling industry, process flow diagrams were developed for each of the facilities, identifying system inputs and outputs.

A life cycle inventory (LCI) of typical ELV management processes was constructed using the case study information; it was supplemented by data from other information sources where necessary. A parts mass study was undertaken to obtain the weights of selected dismantled parts required to construct a mass flow balance of the ELV dismantling/shredding process; this study became a critical component in this research and will be discussed in detail in later sections.

As part of subsequent future research, life cycle assessment methods will be applied to the LCI to determine the impacts resulting from the tradeoffs between alternative processes (including technologies and unit operations) and to identify preferred alternatives.

3.1 Data Collection Challenges

The flow chart in Figure 5 illustrates the LCI data collection pathways. Five of the eight facilities visited agreed to contribute data: four are dismantlers and one is a shredding operation. The collection of data was an intensive and iterative process. Even with site visits, data collection proved to be problematic as a consequence of concerns by industry participants over intellectual and competitive knowledge, as well as the limited availability of facility personnel, time, and onsite resources to provide the data requested. There were significant time delays before facility personnel responded to follow-up inquiries. In addition there was a significant learning curve with respect to understanding what data the industry participants (particularly the dismantlers) would be able to provide and recognizing whether that data would be appropriate for the LCI.

One of the four contributing dismantlers supplied proximate data, instead of actual data, which was based on values acquired from the facility's inventory plus the owner-operator's experience to estimate data gaps. The owner-operator used proxy measures, such as the percentage of a typical car weight, to approximate the masses of the parts recovered for direct reuse, remanufacturing, or recycling. In other cases, such as data for the fluids collection, only basic information, *e.g.*, approximate volumes recovered from typical vehicles were available, and further assumptions, *e.g.*, assuming specific gravities, were needed to account for them on a mass basis. This proximate data is presented and discussed in *Section 5.1.1 Proxy Versus Actual Data*.

The three other contributing dismantlers provided actual unit-based part quantities and recovered fluids quantities by volume and/or mass. The data from these three dismantlers represented parts and materials recovered and sold over a typical operating year. One of the three dismantlers supplied an incomplete data set. The other 2 supplied relatively comprehensive data sets; one included data by vehicle make, model and model year. The operating and production data from the dismantler that supplied data by vehicle make, model and model year was used to construct the dismantling LCI because it was the most comprehensive data set. This data was supplemented with data from other sources to fill in data gaps (*e.g.*, Parts Mass Study).

Data sorting and aggregation had to be done carefully to prevent problems, such as double-counting. By comparing the sorted and aggregated parts count data from the two dismantlers that supplied the most comprehensive data sets, approximately 307 unique part types were identified to be recovered by the participating dismantlers (Figure 6). These part types are listed in Table 38 of Appendix B, along with the respective

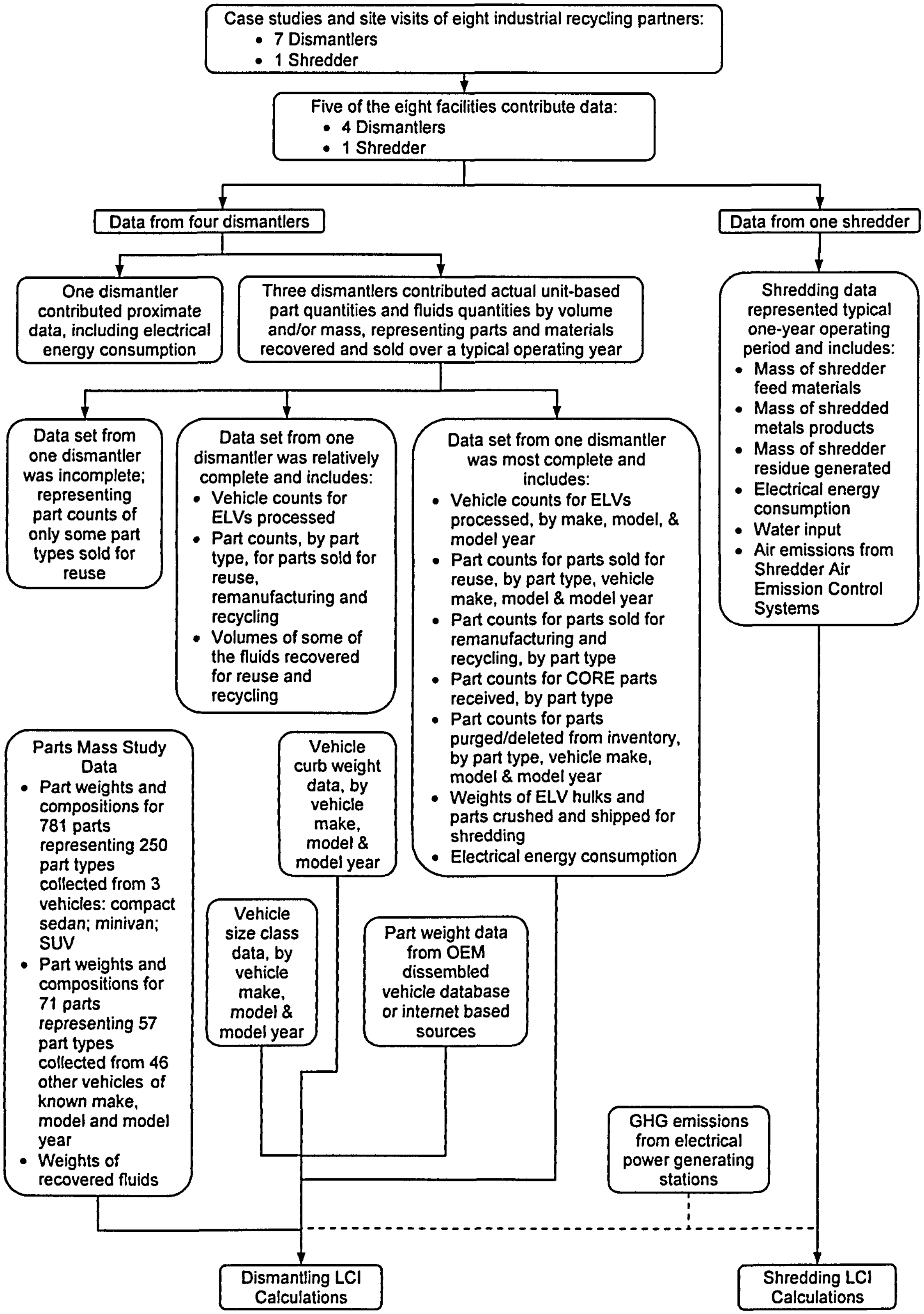
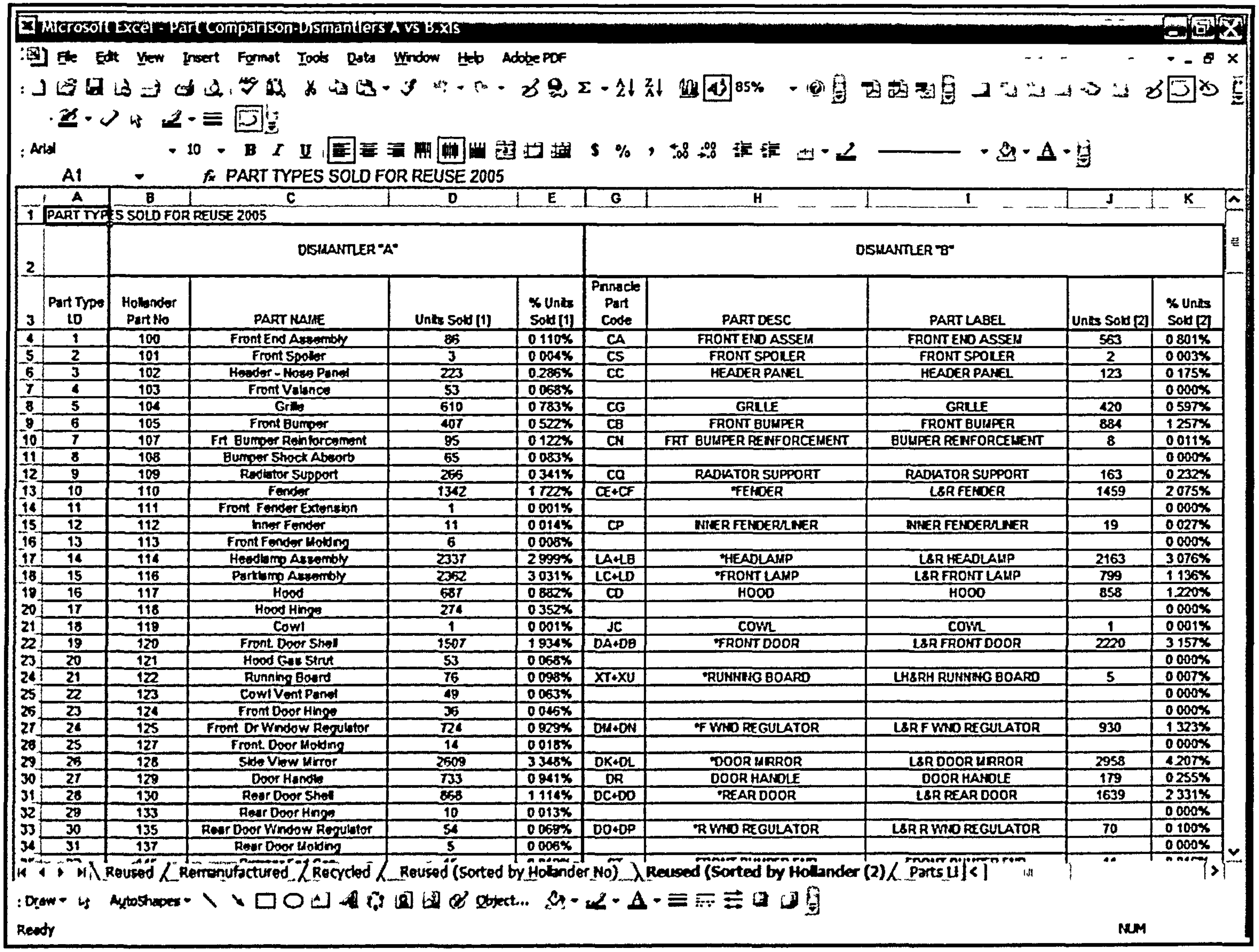


Figure 5 Flow Chart of LCI Data Collection Pathways



A1 PART TYPES SOLD FOR REUSE 2005

	A	B	C	D	E	G	H	I	J	K
1	PART TYPES SOLD FOR REUSE 2005									
2		DISMANTLER "A"				DISMANTLER "B"				
3	Part Type ID	Hollander Part No	PART NAME	Units Sold (1)	% Units Sold (1)	Pinnacle Part Code	PART DESC	PART LABEL	Units Sold (2)	% Units Sold (2)
4	1	100	Front End Assembly	86	0.110%	CA	FRONT END ASSEM	FRONT END ASSEM	563	0.801%
5	2	101	Front Spoiler	3	0.004%	CS	FRONT SPOILER	FRONT SPOILER	2	0.003%
6	3	102	Header - Nose Panel	223	0.286%	CC	HEADER PANEL	HEADER PANEL	123	0.175%
7	4	103	Front Valance	53	0.068%					0.000%
8	5	104	Grille	610	0.783%	CG	GRILLE	GRILLE	420	0.597%
9	6	105	Front Bumper	407	0.522%	CB	FRONT BUMPER	FRONT BUMPER	884	1.257%
10	7	107	Frt Bumper Reinforcement	95	0.122%	CN	FRT BUMPER REINFORCEMENT	BUMPER REINFORCEMENT	8	0.011%
11	8	108	Bumper Shock Absorb	65	0.083%					0.000%
12	9	109	Radiator Support	266	0.341%	CQ	RADIATOR SUPPORT	RADIATOR SUPPORT	163	0.232%
13	10	110	Fender	1342	1.722%	CE+CF	*FENDER	L&R FENDER	1459	2.075%
14	11	111	Front Fender Extension	1	0.001%					0.000%
15	12	112	Inner Fender	11	0.014%	CP	INNER FENDER/LINER	INNER FENDER/LINER	19	0.027%
16	13	113	Front Fender Molding	6	0.008%					0.000%
17	14	114	Headlamp Assembly	2337	2.999%	LA+LB	*HEADLAMP	L&R HEADLAMP	2163	3.076%
18	15	116	Parklamp Assembly	2362	3.031%	LC+LD	*FRONT LAMP	L&R FRONT LAMP	799	1.136%
19	16	117	Hood	687	0.882%	CD	HOOD	HOOD	858	1.220%
20	17	118	Hood Hinge	274	0.352%					0.000%
21	18	119	Cowl	1	0.001%	JC	COWL	COWL	1	0.001%
22	19	120	Front. Door Shell	1507	1.934%	DA+DB	*FRONT DOOR	L&R FRONT DOOR	2220	3.157%
23	20	121	Hood Gas Strut	53	0.068%					0.000%
24	21	122	Running Board	76	0.098%	XT+XU	*RUNNING BOARD	LH&RH RUNNING BOARD	5	0.007%
25	22	123	Cowl Vent Panel	49	0.063%					0.000%
26	23	124	Front Door Hinge	36	0.046%					0.000%
27	24	125	Front Dr Window Regulator	724	0.929%	DM+DN	*F WND REGULATOR	L&R F WND REGULATOR	930	1.323%
28	25	127	Front. Door Molding	14	0.018%					0.000%
29	26	128	Side View Mirror	2609	3.348%	DK+DL	*DOOR MIRROR	L&R DOOR MIRROR	2958	4.207%
30	27	129	Door Handle	733	0.941%	DR	DOOR HANDLE	DOOR HANDLE	179	0.255%
31	28	130	Rear Door Shell	868	1.114%	DC+DD	*REAR DOOR	L&R REAR DOOR	1639	2.331%
32	29	133	Rear Door Hinge	10	0.013%					0.000%
33	30	135	Rear Door Window Regulator	54	0.069%	DO+DP	*R WND REGULATOR	L&R R WND REGULATOR	70	0.100%
34	31	137	Rear Door Molding	5	0.006%					0.000%

Figure 6 Sample of parts count data from the two dismantlers that supplied the most comprehensive data sets. Data is sorted, aggregated and compared to identify the approximately 307 unique part types recovered by the participating dismantlers.

Hollander and Pinnacle inventory system part-type codes used by the participating dismantlers. Part-types that were considered to be symmetrical in nature or construction, such as left and right front doors, were counted as one part type.

Although the part count data supplied by the dismantlers was useful, it was incomplete because it only supplied unit volume information, *i.e.*, the number of parts units sold by part type. An accurate LCI of the dismantling process cannot be constructed based solely on volume. Data about the mass of each part type are required to translate the parts counts into parts mass flows. As a result, alternative sources to obtain parts mass data had to be investigated. These alternatives included:

- OEM provided engineering data;
- Data as listed in parts catalogues;
- Mass of parts measured from a disassembled (reverse assembled) vehicle; and
- Mass of parts measured "in-situ" at the dismantler.

Interestingly, extracting the information from OEM derived engineering data, such as engineered plans or from disassembled (reverse assembly) vehicle data, was considered to be unrealistic due to a number of reasons:

- Proprietary concerns make it difficult to obtain engineering data directly from original equipment manufacturers (OEMs).
- More critically, what is built does not necessarily equal what is recovered; a disassembled vehicle part or sub-assembly is not necessarily equivalent to a dismantled part. This point was emphasized by members of the USCAR Vehicle Recycling Partnership when they were contacted about possible means of obtaining parts mass data.

A part or assemblage of parts recovered by a dismantler may be significantly different than parts or parts configurations as defined by OEM-derived engineering data, or disassembled vehicle data, for a variety of reasons. Part configurations may differ depending on how the parts are physically removed from a vehicle. For example, dismantlers will employ mechanized, semi-destructive dismantling techniques such as cutting, and may sacrifice parts of negligible value to access parts or assemblages that have much higher values for recovery and resale. The actual recovery of parts will vary depending on the dismantling difficulties encountered due to vehicle age, *e.g.*, rust, and construction - many assemblages are simply not intended to be disassembled. Recovered parts will vary based on what parts are in demand and what parts are considered to have recovery value. How a dismantler recovers parts will be customized to optimize their removal and storage. For some dismantling operations, it may be more efficient to isolate and store groups of parts (not just single items as built by OEMs or their suppliers), which can then be dealt with or further dismantled into their constituent parts at a later time.

Ultimately, it was decided that the most effective way to obtain representative parts mass data would be from that measured "in-situ" at the dismantler. As a result, an industry-sponsored study was undertaken to compile part weight data for ELV components and configurations as recovered by dismantlers in the industry.

3.2 Parts Mass Study

With the assistance of one of the participating dismantlers, Standard Auto Wreckers in Scarborough, Ontario, representative parts weights were collected for the 307 selected part types that were identified to be recovered and sold by the participating dismantlers. The Parts Mass Study was carried out in 2 phases. The first phase was carried out over a five-week period, August-September 2007, at Standard Auto Wreckers. The phase 1 work involved parts collection, overall parts mass measurement; and some parts stripping for materials composition determination; large, bulky parts (*e.g.*, engines; door and seat assemblies) and parts determined to be hazardous to ship (*e.g.*, fuel tanks) were stripped at Standard Auto Wreckers. The second phase was performed at the University of Windsor from October 2007 through June 2008 and involved the completion of the parts stripping work to determine materials composition. All the parts recovered but not stripped at Standard Auto Wreckers were each labeled, bagged, packed in gaylord boxes and shipped to the University of Windsor for the second phase, parts teardown work.

During the first phase work, a total of three vehicles - a compact sedan ('97 Neon), a minivan ('96 Voyager) and an SUV ('94 Explorer) - were dismantled by experienced dismantler mechanics to recover approximately 80% (or 250) of the applicable 307 part types; 781 parts were collected from these three vehicles. Another 71 parts representing the other 20% (or approximately 57) of the 307 required parts types (referred to herein as the Miscellaneous Parts) were collected from 46 other vehicles of known make, model and model year, as summarized in Table 10. The majority of the specified part types were collected from vehicles of early- to late-nineties vintage. This approach was deemed to provide a reasonably accurate and complete

Table 10 Summary of vehicles from which the Misc. Parts were collected

Year	Make	Model	Year	Make	Model
1977	Chevrolet	Caprice Sedan	1995	Volvo	850 Sedan
1984	Oldsmobile	Cutlass Supreme	1995	Cadillac	DeVille
Circa 1986	Ford	Pick-up (with 302 cu. in. V-8 engine)	1995	Cadillac	Seville STS Sedan
1986	Chevrolet	C 3500 Pickup (2-wheel drive)	1995	Chevrolet	Cavalier
1990	Cadillac	(with FWD)	1995	Ford	Probe
1991	Buick	Regal	1995	Pontaic	Grand Prix
1991	Chevrolet	K 2500 Pickup (4-wheel drive)	1996	Cadillac	Seville Sedan
1991	Chevrolet	K 3500 Pickup (4-wheel drive)	1996	Chevrolet	1500 Pickup
1991	Mercury	Grand Marquis	1997	Chevrolet	Venture
1991	Pontiac	Sunbird	1997	Chevrolet	1500 Pickup
1992	Acura	Integra	1998	Ford	F150 Pickup
1992	Dodge	Daytona	1998	GMC	Jimmy
1992	Ford	Thunderbird Coupe	1998	GMC	Savana G2500
1992	Saturn	SL Sedan	1998	Honda	Prelude
1992	Ford	Ranger Pickup	1998	Plymouth	Voyager
1993	Cadillac	DeVille	1999	Honda	Civic
1993	Chevrolet	Lumina Euro	2000	GMC	Sierra 1500 (1/2-ton) Pickup
1993	Plymouth	Acclaim Sedan	2002	Ford	Escape XLT
1993	Pontiac	Bonneville	2002	Jeep	TJ Wrangler
1993	Saturn	SL Sedan	2004	Ford	Crown Victoria
1994	GMC	Jimmy	2005	Dodge	Caravan
1994	Jeep	Cherokee	2006	Dodge	Caravan
1994	Suzuki	Sidekick	2006	GMC	Sierra 2500 (3/4-ton) Pickup

data set for the 307 most commonly identified part types targeted by dismantlers given the scope of this research and the resources available.

Prior to dismantling the compact sedan ('97 Neon), the minivan ('96 Voyager) and the SUV ('94 Explorer), each vehicle was weighed on a certified truck scale and the weight subsequently recorded. With exception of the refrigerants, fluids were recovered from each vehicle by the dismantler mechanics by gravity drainage and then weighed and recorded. Refrigerants were recovered from the vehicles, prior to any parts removal, using negative-pressure refrigerant recovery equipment. As each part or parts assemblage was collected, pictures were taken and the overall part weight was measured and recorded. The following scales were used for weight measurement:

1) Western Scale Co. Ltd. certified truck scale, Model #NTEP00-076A1, 85,000 lb capacity (± 20 lbs);

2) Canadian Toledo Scale Co. Ltd. L19, Style 31-1821 platform scale, 1600 lb capacity (± 1.0 lbs);

3) Pelouze Model 4040 digital scale, 180 kg capacity (± 0.2 kg);

4) Denver Instruments Model XP-1500 digital scale, 1500 g capacity (± 0.05 g).

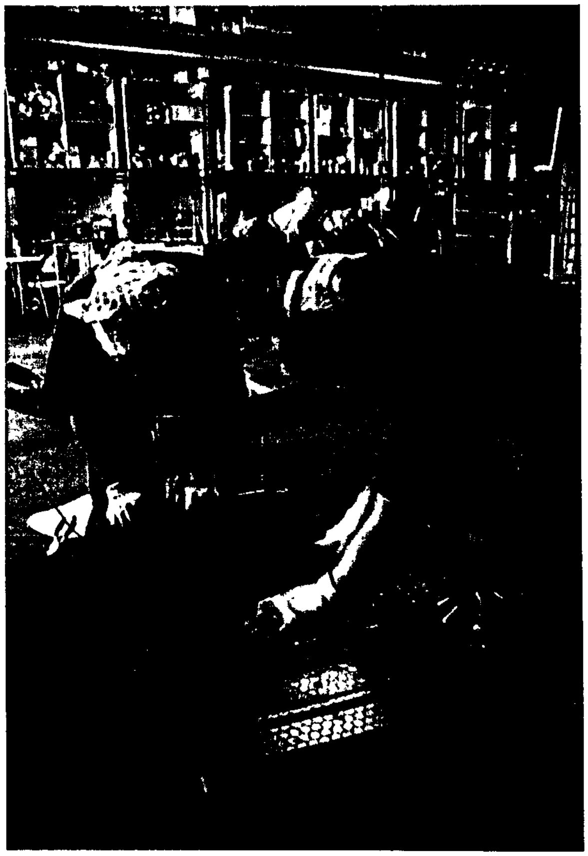


Figure 7 University of Windsor researchers at work stripping a typical Floor Pan section to determine materials composition.

After determining overall part weight each part was stripped to determine general materials composition in two major categories: (1) metals and (2) non-metals, Figure 7. When it was practicable, the metals where further segregated as ferrous and non-ferrous metals. A magnet was used to distinguish between the ferrous and non-ferrous metals, which is representative of how the separation of ferrous metals from non-ferrous, nonmagnetic materials is accomplished in a shredding process. As a result, non-ferrous metals will include high-grade stainless steels in this research.

The materials from each stripped part were weighed and photographed. Figure 8 shows an example of a Rear Seat, both before and after stripping, with the materials segregated as metals and non-metals.

A variety of techniques were used by the dismantlers to recover the specified parts, Figure 9. Power tools, including a reciprocating saw, impact wrench, drill, die grinder, impact ratchet, air chisel, and angle grinder with cutoff wheel, were used by the dismantlers, in preference to manual hand tools wherever practical. On occasion, a torch was required to facilitate the removal of certain parts due to corroded fasteners. To assess the difficulty and time required to remove the parts, the dismantling activities were video recorded for later review and analysis. This additional video-based analysis may be useful for identifying how the initial design of parts and assemblages could later benefit dismantling efforts.

Figure 8 Example of stripped Rear Seat materials (metals and non-metals).

Figure 9 Dismantler at Standard Auto Wreckers making Quarter Panel Assembly cuts using a reciprocating saw.

All the data collected from the parts dismantling and stripping work was entered into Excel spreadsheets. In this research, the weights of the dismantled parts from the three vehicles and the Misc. Parts were applied to the part counts to determine parts mass flows, which were subsequently used to construct the LCI. The development of the LCI is presented in detail in Chapters 5 and 6.

The stripped materials weights will be used at a later date to expand the LCA and evaluate the dismantling process with respect to materials reuse and recycling. In addition, by comparing the dismantled parts data to the existing representative OEM disassembled parts data, by specific vehicle make, model, and model year, the OEM disassembled parts data may be reconciled or harmonized with the dismantler data by weight and composition. By understanding how to aggregate the OEM disassembly data to “create” or mimic a dismantled part, by weight and composition, OEM disassembled parts data for other vehicle makes and models can be used to estimate representative dismantled parts weights for vehicles of a variety of vehicle classes. This information may then be applied to further expand or refine the LCA of the dismantling process and evaluate it, for example, with respect to vehicle type, vehicle class, and vehicle age.

4 CASE STUDIES

Site visits were conducted at three dismantling facilities in Ontario, one dismantler in Saskatchewan, three dismantlers in British Columbia and one Ontario shredding facility. The following sections describe the ELV management activities practiced by these facilities and highlight the similarities and significant differences between them.

4.1 Dismantling Facility Site Visits

The dismantlers that were visited are principally "full-service" facilities. These companies dismantle the ELVs they receive, using in-house personnel, recovering and inventorying the resellable parts, as well as inspecting, testing and cleaning the parts as may be required prior to their sale.

One of the participating dismantlers operates a self-service facility (commonly called a "UPIC" or "U-Pull-It" facility). ELVs are placed into a yard where customers may come and pull the parts themselves using their own tools, and buy them at a reduced price.

The processing through-put capacity of the facilities varied considerably, from as few as 500 ELVs per year to close to 17,000 ELVs per year (refer to Table 11). The processing capacities of the facilities depend on space availability, parts inventory/storage strategies, and the types of ELVs managed.

Table 11 Comparison of ELVs processed by the participating dismantlers

Dismantler	Process Through-put, (ELVs/yr)	Exclusively Total Loss/Late Model Vehicles	Total Loss/Late Model Vehicles and Old Age/Early Model Vehicles
A	17,000	N	Y (2000/15000)
B	5000	N	Y (2500/2500)
C	3000	N	Y (1500/1500)
D	2000	Y (2000)	N
E	n.a.	Y	N
F	500	Y(500)	N
G	n.a.	Y	N

n.a. = information not available; Y = yes; N = no

The types of ELVs processed by the participating dismantlers varied. Some of the dismantlers exclusively process vehicles from vehicle insurance companies that:

1) are accident/collision vehicles retired as vehicle 'write-offs' as a result of damage by collision or impact; also referred to as total loss vehicles (TLVs); and

2) are late-model vehicles having high parts salvageability.

The other dismantlers process both total loss/late-model vehicles (vehicles with high parts salvageability), as well as vehicles of little or no parts salvage value. This latter class of vehicle includes old age/early-model vehicles and vehicles written off as a result of severe damage by collision, impact, fire, or flood. A vehicle retired due to old age is typically an early model vehicle in poor mechanical and/or physical condition.

Figures 46 to 48 in Appendix B illustrate three examples of the process flow diagrams for the participating dismantlers. Although there are differences between each dismantler, in general the ELV process methodologies used by the dismantlers were similar. Vehicles that enter the ELV management process are typically inspected and evaluated by the dismantlers according to their make, model, model year, physical condition, and by the value and demand for particular automotive parts. They are consequently classified and managed as either "high salvage/late-model" vehicles or "low salvage/old-age" (early-model) vehicles after entering the facility. High salvage-value parts are identified and their respective parts information and vehicle administration data is entered into computer-based parts inventory systems. Fluids and hazardous parts and materials are recovered and directed for reuse, recycling, energy recovery, and/or disposal

Table 12 summarizes the fluids recovered (or not recovered) by the dismantlers and their most common disposition. All of the dismantlers bulk up and recycle their used lubricants – engine oil, transmission oil, differential fluid, brake-line fluid and/or power steering fluid - by shipping the lubricants offsite by a licensed waste hauler for recycling.

Table 12 Summary of fluids recovered by the participating dismantlers

	By all of the participating dismantlers	By most of the participating dismantlers (5 or more)	Common Disposition
Refrigerant	X		Reused
Gasoline	X		Reused
Motor/Engine Oil	X		Recycled
Transmission Oil	X		Recycled
Antifreeze	X		Reused
Differential Fluid (a.k.a. Gear Oil)		X	Recycled
Brake Fluid		X	Recycled
Power Steering Fluid		X	Recycled
Windshield Washer Fluid		X	Reused

Alternatively, they may use the used oils on-site for comfort heating in used oil-fired space heaters. The recovered refrigerants, antifreeze, gasoline and/or windshield washer fluid are reused on-site by the dismantlers or sold to customers for off-site reuse.

Which hazardous parts and materials are removed from ELVs varies somewhat amongst the participating dismantlers. Batteries are removed by all. Un-deployed airbags are either: (1) removed for reuse in jurisdictions that permit this, (2) are deployed and left in the vehicles, (3) removed, deployed and sent with the ELV hulks for shredding. Most of the participating dismantlers remove mercury-containing switches under voluntary switch removal programs, such as the voluntary Switch Out Program coordinated by Canada's Clean Air Foundation. Some of the participating dismantlers remove lead wheel weights. Tires are considered unacceptable shredder feed materials; they are removed by the dismantlers and either sold for reuse or sent for recycling.

The parts removal and storage practices used by the participating dismantlers vary. Based on their assessment of the "principal" high salvage-value parts targeted for recovery and sale as reusable parts, a number of the participating dismantlers remove these high value parts first, then place the "leftover" ELVs into inventory yards where inventoried parts are stored "on-board" the ELVs themselves for a certain period of time. This process allows the dismantlers access to other salvageable, but less popular parts, that are removed from the ELVs only after the higher value parts have been sold. Other dismantlers will strip any and all reusable parts identified for salvage, store only these parts, and not maintain yard storage of ELVs with on-board inventoried parts. If the dismantlers do not have a particular part a customer is looking for, they may provide a "brokered part", a part brought in from another dismantler who has the part in inventory.

Salvageable parts that are removed from the ELVs and determined to be unsuitable for sale as a reusable part, but are refurbishable, will commonly be sold by the dismantlers to parts remanufacturers. Parts that the participating dismantlers will consider as rebuildable include engines, starters, AC compressors, water pumps, carburetors, calipers, power steering pumps, carrier assemblies, alternators, transmissions, axle assemblies and transfer cases.

Some parts are removed by the dismantlers for recycling independently of the ELV hulks, because they (1) are of greater value to the dismantlers if recycled separately, *e.g.,* catalytic converters, and/or (2) are unsuitable or unacceptable shredder feed materials, *e.g.,* batteries, tires.

The dismantler that operates the self-service facility generally places vehicles in their UPIC yard that are too low in value to justify their being dismantled, but have not yet deteriorated to the condition or reached the age to be simply crushed and shipped for shredding. These vehicles typically have parts on-board that still have some value to customers who are willing to recover the parts themselves at a lower cost. The vehicles that are placed in the self-service yard are first prepared by removing at least the fluids, refrigerants, tires, catalytic convertors, and hazardous or environmentally sensitive components, such as mercury switches.

All the participating dismantlers apply "Cash-On-REturn" or CORE charges on certain part types. A CORE part is a part that may be received from a customer for return of a CORE deposit or charge. A "CORE charge" is a refundable deposit for the value of the CORE part that is paid at the time a "new used" part is purchased. The CORE part may be traded in for the credit of a portion of the price of the "new" used part being purchased. For example, instead of paying full price for a new part, such as an alternator, an old alternator can be submitted as a CORE and consequently reduce the price that the customer would have to pay for a "new" used alternator. Pumps, injectors, engines, starters, alternators, transmissions and torque converters are all common examples of parts that CORE charges may be applied to. CORE parts received by a dismantler will sometimes be sold as parts for reuse, but most commonly sold with parts for remanufacturing or recycling.

In the dismantling industry, parts that are recovered and directed for remanufacturing are generally referred to by dismantlers as "cores". Analogous to an "apple core", a "core" is typically what results if a recovered part or part assemblage is determined to unsuitable for sale as a reusable part, but may be sold as a remanufacturable part. An engine assembly, for example, that is tested and determined to be unsuitable for direct reuse may be stripped of reusable parts, leaving a "core" which itself may have value as a remanufacturable part. The concept of "Cash-On-Return" or CORE parts versus remanufacturable "cores" can be a source of confusion. CORE parts can be directed for remanufacturing as cores, but CORE parts are not necessarily a dismantler's only source of remanufacturable cores. Dismantlers will target certain part types in their high salvage-value, late-model ELVs for recovery and resale as remanufacturable cores. In this research, to avoid confusion with "Cash-On-Return" or CORE parts, a part recovered and directed for remanufacturing will be referred to simply as a remanufacturable part, not as a remanufacturable "core".

To facilitate the removal of the high salvage-value parts that the dismantlers target for recovery, other parts of little or no value may have to be removed first to make the desired parts accessible. Typically these no-value parts are returned to the stripped vehicle and sent for shredding with other ELV hulks. Some stripped part types may not be returned to the ELVs, but will be shipped in segregated loads for shredding and metals recycling, *e.g.*, steel or aluminum wheels.

Periodically the dismantlers perform an inventory clean-up. Dead or overstock parts inventory is removed, or "scrapped-out", and sent for shredding with the ELV hulks. ELVs that are to be scrapped-out and have parts inventoried on-board are reviewed for salvageable parts to be kept. Those parts are removed from the ELVs and the remaining hulks are sent for shredding.

Several of the participating dismantlers compact their leftover ELV hulks, along with scrapped-out parts, prior to shipping them to the shredders using either their own on-site car crushers or contracted portable car crushers. Compaction maximizes the number of ELV hulks that may be shipped at one time at the most economical cost while satisfying shipment height restrictions where applicable. Some of the dismantlers can ship their ELV hulks and scrapped out parts without crushing them because of their close proximity to receiving shredding facilities and their low ELV processing throughputs, *e.g.*, two or less ELVs per day.

4.1.1 Dismantling Process

Despite the differences observed between the dismantling facilities visited, the process flow diagrams of the facilities can be simplified into one overall flow diagram accounting for the inputs and outputs common to all the dismantlers. This overall dismantling process flow diagram is illustrated in Figure 10, which will serve as the basis for the development of the dismantling life cycle inventory. The process inputs and outputs include:

1) ELVs received and processed;
2) parts recovered and directed for reuse, remanufacturing, and recycling independently of shredding and metals recovery;
3) CORE parts received;
4) energy used (electricity and fuels);
5) water used;
6) fluids recovered from ELVs and directed for reuse, recycling, energy recovery and disposal;

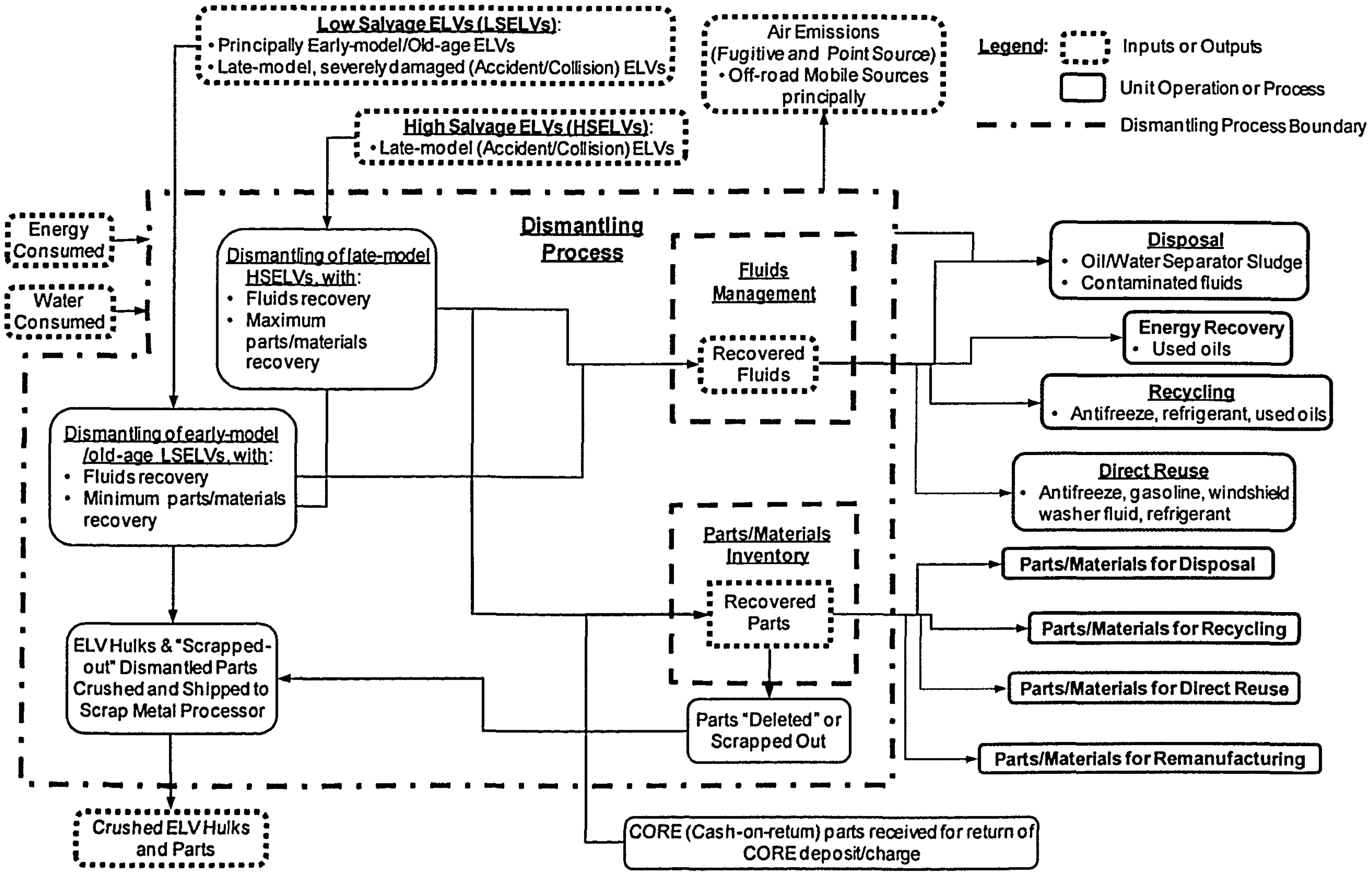


Figure 10 Simplified process flow diagram of the typical process used by the participating dismantlers.

7) ELVs hulks and parts deleted from inventory that are crushed and shipped for shredding;
8) waste water; and
9) air emissions.

The vehicles entering the ELV management process will be referred to as "high-salvage" end-of-life vehicles (HSELVs) and "low-salvage" end-of-life vehicles (LSELVs). LSELVs will principally be represented by "early-model", old-age vehicles, retired as a result of poor mechanical and/or physical condition or as a consequence of age and/or damage (by collision, impact, fire, or flood). LSELVs may also be late-model vehicles that are so severely damaged by collision or impact that there are little or no recoverable parts for reuse. LSELVs will be processed for fluids and hazardous materials recovery and minimum parts recovery. In contrast, HSELVs consist mainly of "late-model" vehicles, retired as a consequence of limited damage by collision or impact, and are processed for fluids and hazardous materials recovery, and maximum parts recovery.

Recovered fluids, depending on type, quality and quantity, will be reused, recycled, directed for energy recovery, or for disposal. Recovered antifreeze; gasoline; windshield washer fluid and refrigerant are typically directed for reuse. Recovered oils may be recycled or used for comfort heating via used oil-fired space heaters. Oil/water separator sludge from parts washing systems will typically be shipped for disposal. Parts recovered from the dismantled vehicles, will be sold for direct reuse, for remanufacturing and reuse, for recycling or sent for disposal. Parts typically recovered for remanufacturing include AC compressors, water pumps, carburetors, calipers, power steering pumps, carrier assemblies, alternators, starters, transmissions, axle assemblies, engines and transfer cases. Parts recovered for recycling include batteries, catalytic converters, radiators and tires. Plastic fuel tanks and mercury switches are examples of parts that may be recovered and directed for disposal.

CORE parts that are received may be directed for reuse, remanufacturing (if not directly reusable) or recycling (if not remanufacturable). Unsold parts that are deleted or purged from inventory are generally crushed with the ELV hulks and shipped for shredding.

Electrical energy consumed in the dismantling process is generally used for lighting and operation of office equipment (computers in particular), for comfort heating, as well as for operating power tools and equipment used in the dismantling process, such as hoists, compressors, and car crushers. Fuels consumed in the dismantling process are typically used for comfort heating, *i.e.,* natural gas, fuel oil, and/or used oil, and for powering on-site vehicles, such as trucks, forklifts and front-end loaders, *i.e.*, propane, gasoline, and diesel fuel.

Water consumed in the dismantling process is most commonly used for cleaning dismantled parts to remove dirt, oil and grease prior to selling the parts to customers. To conserve water and reduce the amount of waste fluids generated, dismantling facilities use closed-circuit parts washing systems: wash water is treated and reused within the system. Waste water generated as a consequence of water used in the dismantling process - typically oil/water separator sludge produced in a parts washing system - will be shipped by a contracted licensed waste hauler for off-site disposal.

The on-site collection and treatment of contact storm water generated from precipitation is not required at the dismantling facilities that were visited. The dismantlers apply best management practices (BMPs) such as carrying out fluids and parts recovery inside buildings equipped with fluid containment systems, and storing oil-wetted parts on an impervious pad inside a building or under a roof. The application of the BMPs ensures fluids, batteries and other materials of potential environmental concern are removed and managed to minimize or prevent the discharge of waste to the environment in accordance with applicable regulations.

Air emissions from the dismantling process are principally generated by off-road mobiles sources in the form of point source emissions, such as from combustion emissions from diesel-, gasoline- and/or propane-fueled off-road vehicles, *e.g.,* front-end loaders and/or forklifts, and fugitive emissions such as road dust from on-site vehicular traffic on paved and/or unpaved surfaces. Point source air emissions from the dismantling process may also be generated by on-site comfort-heating and/or hot water-heating combustion sources, such as hot water tanks and/or space heaters.

4.2 Shredding Facility Site Visit

Figure 11 illustrates a simplified process flow diagram for the shredding facility that was visited. This facility will serve as the basis for the development of the shredding life cycle inventory. The inputs and outputs of the shredding process include:

1) Crushed ELV hulks and unsold parts, as well as other loose clean metals-rich scrap, *e.g.*, construction and demolition scrap, received and processed;
2) Energy used (electricity and fuels);
3) Water used;

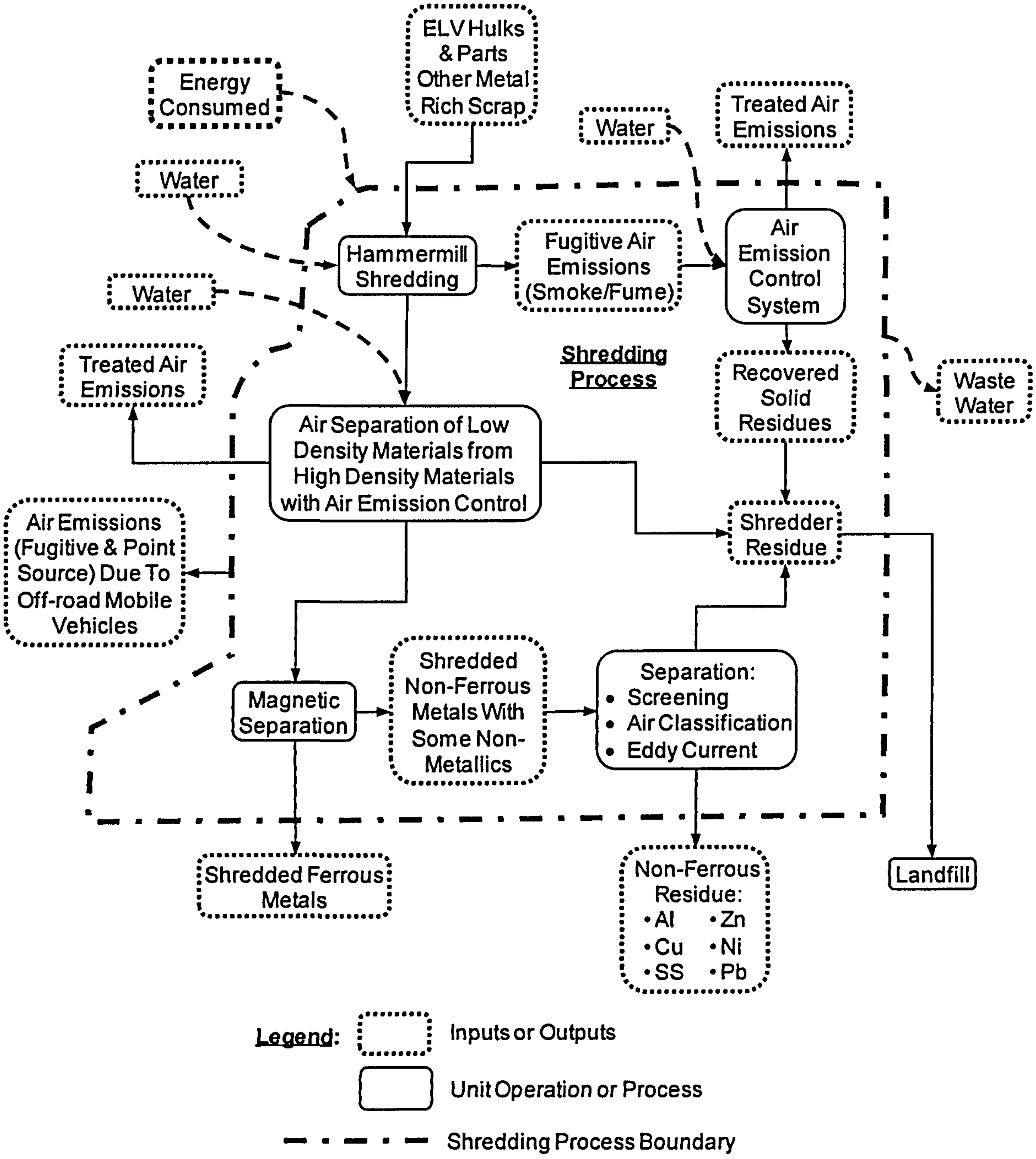


Figure 11 Simplified process flow diagram for the shredding process.

4) Shredded ferrous metals and non-ferrous residue products, recovered and shipped for metals processing and refining;
5) Air emissions, point source and fugitive;
6) Waste water that is collected, treated, and discharged; and
7) Shredder residue generated and disposed of by landfilling.

The shredded material discharged from the mill is further processed by air separation of the low density, non-metallic materials from the higher density, metal-rich fraction. This metal-rich fraction is subsequently processed, by magnetic separation, to separate the ferrous metals, *i.e.*, cast iron and carbon steel, from the non-ferrous and non-magnetic metals, *e.g.*, aluminum, copper, zinc, nickel, stainless steel, and lead.

The predominantly non-ferrous, non-magnetic metal fraction, containing high grade stainless steels (SS), as well as some low density, non-metallic materials, is further processed using a combination of screening, air classification and eddy current separation methods to improve metals recovery. The resulting mostly non-ferrous metal product is shipped to recycled metals processors for additional processing and treatment to separate the materials into individual metal fractions that are of sufficient purity for subsequent metal refining. The shredded ferrous metal product is recycled as alternative steel mill feed stock. The left-over, mostly non-metallic shredder residue (SR) is routinely disposed of by landfilling.

As illustrated in Figure 11, water is strategically added into the shredding process in the mill and air separation/emission control systems in controlled nominal quantities to control mill temperature, to prevent fires, and to help control fugitive air emissions generated by the process but without saturating the low density, non-metallic materials. The generation of process waste water is negligible due to evaporation and the tight control on process water addition. Contact storm water generated by precipitation is collected and directed to an on-site storm water retention pond for subsequent treatment prior to discharge.

Energy consumed in the shredding process includes electricity used for lighting and the operation of the motorized equipment, *e.g.*, the shredder, magnetic separators, screens, eddy current separators, conveyors, pumps, and fans/blowers, and diesel fuel used in on-site vehicles, *i.e.*, front-end loaders and cranes. Air emissions from the shredding process include:

1) point source emissions from air separation and emission control equipment;
2) point source emissions generated by off-road mobiles sources in the form of combustion emissions from diesel-fueled off-road vehicles, *e.g.,* front-end loaders and cranes;
3) fugitive emissions as a consequence of materials handling activities and equipment such as at conveyor transfer points, loading of scrap materials on to

the shredder feed conveyor, and loading of shredded metal products for shipment; and

4) fugitive emissions such as road dust from on-site vehicular traffic on paved and/or unpaved surfaces.

5 VEOL LCI DEVELOPMENT - DATA COLLECTION

Of the eight facilities visited, LCI data was contributed by four of the dismantlers and from the shredding operation.

5.1 LCI of the Dismantling Process

Figure 12 highlights the input and output data collected for the LCI of the dismantling process, as well as the boundaries that the LCI/LCA will be based on. A gate-to-gate inventory analysis of the dismantling process is undertaken, but excludes:

1) the preceding stage of ELV shipment to the dismantler and its associated fuel inputs and associated air emissions,
2) the succeeding shipment of ELV hulks and parts to the shredder and its associated fuel inputs and associated air emissions,
3) the fuel inputs into the dismantling process, for comfort heating and for on-site vehicle operation,
4) the air emissions from the dismantling process - point source emissions from comfort heating and off-road mobile sources, and fugitive emissions from on-site traffic,
5) the process water input, and
6) oil/water separator sludge generated in parts washing systems.

The eco-efficiencies of ELV shipment to the dismantler will vary depending on the methods of delivery (*e.g.*, towed versus driven), distances travelled, type of fuel input (*e.g.*, gasoline versus diesel), vehicle engine type, age, HP, and operating efficiency (*i.e.,* load factor). Similarly eco-efficiencies of ELV hulks and parts shipment to shredders will vary according to load size (*e.g.*, crushed versus uncrushed loads), distances travelled, type of fuel input (*e.g.*, gasoline versus diesel), vehicle engine type, age, HP, and operating efficiency (*i.e.,* load factor).

Eco-efficiencies of comfort heating systems and off-road mobile equipment used in the dismantling process will vary depending on the types of fuel and equipment used, and equipment operating hours, and therefore will affect the air emissions generated by these point source systems. Fugitive emissions from on-site traffic will be influenced by the type and condition of on-site roadway/traffic areas (*e.g.*, paved versus unpaved areas; swept versus un-swept paved areas), vehicle sizes, distances traveled, weather conditions and road way dust-type and properties (*e.g.*, aerodynamic particle size).

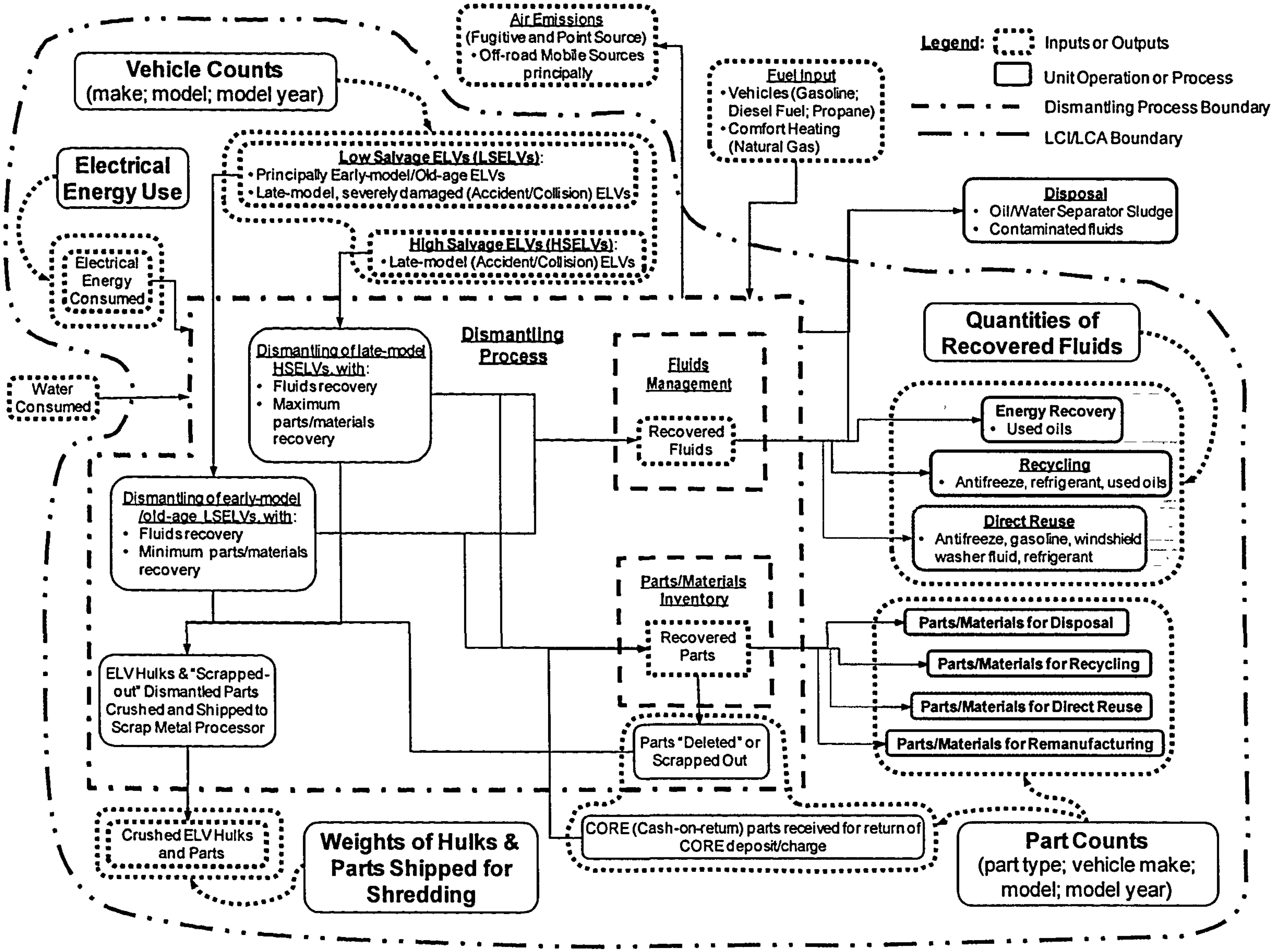


Figure 12 Dismantling process flow diagram illustrating the LCI/LCA boundary and the data contributed for the LCI.

While dismantling facilities are similar to one another in terms of what they dismantle and the methods employed, the individual configuration of the facilities and infrastructure can vary considerably. These factors complicate any efforts to generalize the type and amounts of emissions from dismantling facilities.

Water consumed in the dismantling processes of the participating dismantlers is used in closed-circuit parts washing systems. Waste water generated as a consequence of water use in these parts washing systems consists of oil/water separator sludges that are periodically shipped off-site for disposal. Water consumption in these closed-circuit parts washing systems will vary with water evaporation rates and the frequency and volume of oil/water separator sludge shipped off site for disposal. Oil/water separator sludge generation rates in the parts washing systems is expected to vary, principally, with the quantities, sizes and initial condition of the parts processed.

The eco-efficiencies associated with the processes described above are expected to be significant. They have been excluded from this analysis as a consequence of the lack of readily available data, time constraints, and limitations in the scope of this research. These processes should, however, be reviewed as part of future research to assess the significance of their impacts and to see how they relate proportionally to overall site impacts.

With the exception of the dismantler that supplied the proxy data, the contributed data represents a typical one-year operating period (2005 dismantling data). As illustrated in Figure 12, the dismantling process data that was contributed includes:

1) vehicles counts for HSELVs and LSELVs received and processed, by vehicle make, model and model year;
2) part counts, for:
    a. parts sold for reuse, remanufacturing, recycling, by part type, vehicle make, model and model year;
    b. parts deleted from inventory, by part type, vehicle make, model and model year; and
    c. CORE parts received (for reuse, remanufacturing and/or recycling);
3) volumes of fluids recovered;
4) weights of ELVs hulks and deleted parts crushed and shipped for shredding; and
5) energy use.

5.1.1 Proxy Versus Actual Data

The dismantler that provided proximate data used proxy measures, such as the percentage of a typical car weight (*i.e.*, 1496 kg/vehicle) combined with their experience, to estimate the masses of the parts recovered for direct reuse, remanufacturing, or recycling. In the case of fluids, only basic information (*e.g.*, approximate volumes recovered from typical vehicles) were provided, and further assumptions (*e.g.*, assuming specific gravities) were needed to account for them on a mass basis. Surrogate data sources had to be used to supplement the site specific data. Table 13 shows the output from the assessment of the proxy data. Building the data set to create this table proved to be an intensive and iterative process.

The data shown in Table 13 represents data that can be acquired with limited industry participation and supplemented by external data assumptions. However, follow-up efforts with other industry participants succeeded in refining the data acquisition process, resulting in a much more comprehensive and credible data set consisting of actual unit-based recovered part quantities and recovered fluids quantities by volume and/or mass. As part of future research, the trade-offs of performing a "detailed" LCA using actual data versus an "approximate" LCA using proxy data will be assessed.

5.2 LCI of the Shredding Process

Figure 13 highlights the input and output data collected for the LCI of the shredding process, as well as the boundaries that the LCI/LCA will be based on. A gate-to-gate inventory analysis of the shredding process is proposed with exclusion of:

1) the preceding stage of ELV hulks and parts shipment to the shredder and its associated the fuel inputs and associated air emissions;
2) the succeeding shipment of the shredded ferrous and non-ferrous metal products for recycling and shipment of shredder residue for disposal and its associated fuel inputs and associated air emissions;
3) the fuel inputs for on-site mobile equipment operation; and
4) the air emissions - fugitive and point source - from on-site mobile sources.

The eco-efficiencies associated with the shipment of ELV hulks and parts to shredders, fuel input and resulting combustion emissions, will vary according to load size (*e.g.*, crushed versus uncrushed loads), distances travelled, type of fuel input (*e.g.*, gasoline versus diesel), vehicle engine type, age, HP, and operating efficiency (*i.e.*, load factor). Similarly eco-efficiencies of the shipment of shredded metal products and wastes

Table 13 Summary of LCI Data for a Canadian Dismantling Facility

				Quantities Reused, Recycled and/or Disposed								
				By Unit Volume and/or Weight			By Weight		By Weight		Weight Ratios	
				Units	Scrap Vehicles	Accident / Collision Vehicles (generally vehicles <=10 years old)	Scrap Vehicles	Accident / Collision Vehicles	Scrap Vehicles	Accident / Collision Vehicles	Scrap Vehicles	Accident / Collision Vehicles
							Tonnes/month	Tonnes/month	% Wgt	% Wgt	Kg/ELVtonne	Kg/ELVtonne
Inputs	Vehicles Received / Processed			# of Units/month	125	125						
				Tonnes/month	187	187	187	187				
Output	Fluids Removed / Recovered	Gasoline (Sp Gr = 0 74)	Reused Onsite	Litres/month	750	750	0 56	0 56	0 30%	0 30%	2 97	2 97
			Reused Offsite	Litres/month	3000	3000	2 22	2 22	1 19%	1 19%	11 87	11 87
		Motor oil (Sp Gr = 0 87)	Reused Onsite for Space Heating (90%)	Litres/month	450	450	0 39	0 39	0 21%	0 21%	2 09	2 09
			Shipped for Disposal (10%)	Litres/month	50	50	0 04	0 04	0 02%	0 02%	0 23	0 23
		Transmission fluid (Sp Gr = 0 90)	Reused Onsite for Space Heating (90%)	Litres/month	675	675	0 6	0 6	0 32%	0 32%	3 25	3 25
			Shipped for Disposal (10%)	Litres/month	75	75	0 1	0 1	0 04%	0 04%	0 36	0 36
		Antifreeze (Sp Gr Ethylene glycol = 1 12 Sp Gr Propylene glycol = 1 038)	Reused Onsite	Litres/month	50	50	0 1	0 1	0 03%	0 03%	0 30	0 30
			Reused Offsite	Litres/month	450	450	0 5	0 5	0 27%	0 27%	2 70	2 70
		Rear Differential fluid (≈ 1 5 litres/ELV @ Sp Gr = 0 90)	Reused / Recycled / Disposed of	Litres/month	0	0	0 0	0 0	0 00%	0 00%	0 00	0 00
		Brake fluid (≈ 0 5 litres/ELV @ Sp Gr = 1 05)	Reused / Recycled / Disposed of	Litres/month	0	0	0 0	0 0	0 00%	0 00%	0 00	0 00
		Powersteering fluid (≈ 0 75 litres/ELV @ Sp Gr = 0 87)	Reused / Recycled / Disposed of	Litres/month	0	0	0 0	0 0	0 00%	0 00%	0 00	0 00
		Windshield washer fluid (≈ 2 0 litres/ELV @ Sp Gr = 0 96)	Reused / Recycled / Disposed of	Litres/month	0	0	0 0	0 0	0 00%	0 00%	0 00	0 00
		Refrigerant	Reused	Litres/month	2 tanks	3 tanks						
	Parts Recovered for Direct Reuse (Resale)		Other	Tonnes/month	60	110	60	110	32 09%	58 82%	320 86	588 24
			Tires	Tonnes/month	1 25	1 25	1 25	1 25	0 67%	0 67%	6 68	6 68
	Parts Recovered for Remanufacturing or Reconditioning		Starters Alternators Air Conditioner Compressors	Tonnes/month	2	1 5	2	1 5	1 07%	0 80%	10 70	8 02
	Parts/Materials Recovered for Recycling		Catalytic convertors	Tonnes/month	0 5	0 5	0 5	0 5	0 27%	0 27%	2 67	2 67
			Aluminum rims	Tonnes/month	2	1 5	2	1 5	1 07%	0 80%	10 70	8 02
			Steel rims	Tonnes/month	1	0 5	1	0 5	0 53%	0 27%	5 35	2 67
			Copper radiators	Tonnes/month	0 5	0	0 5	0	0 27%	0 00%	2 67	0 00
			Aluminum radiators	Tonnes/month	1	0 5	1	0 5	0 53%	0 27%	5 35	2 67
			Batteries	Tonnes/month	2	2	2	2	1 07%	1 07%	10 70	10 70
			Tires	Tonnes/month	1 25	1 25	1 25	1 25	0 67%	0 67%	6 68	6 68
	Entire Vehicles Sold for Reuse			Tonnes/month	3	18	3	18	1 60%	9 63%	16 04	96 26
	ELV Hulks Materials Shipped to Shredder			Tonnes/month			108 1	45 6	57 78%	24 36%	577 83	243 61

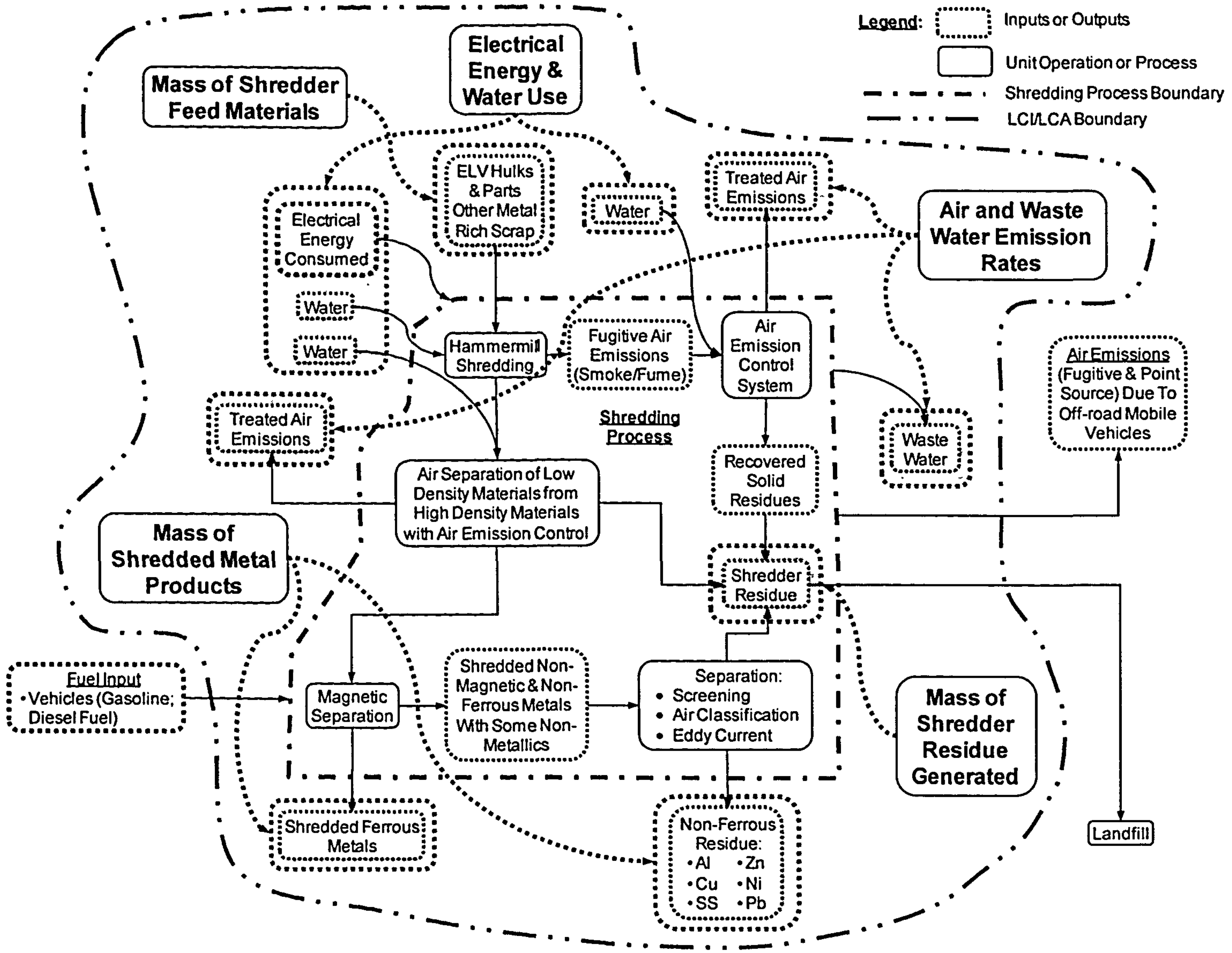


Figure 13 Shredding process flow diagram illustrating the LCI/LCA boundary and the data contributed for the LCI.

for recycling or disposal will vary according to load size, distances travelled, type of fuel input, vehicle engine type, age, HP, and operating efficiency.

Eco-efficiencies of mobile equipment used in the shredding process will vary depending on the type of fuel used (*e.g.*, diesel versus gasoline), type of equipment used (*e.g.*, crane, front end loader), and equipment operating hours, and therefore will affect the air emissions generated by these point source systems. Fugitive emissions from on-site traffic will be influenced by the type and condition of on-site roadway/traffic areas, (*e.g.*, paved versus unpaved areas; swept versus un-swept paved areas), vehicle sizes, distances traveled, weather conditions, and road way dust-type and properties (*e.g.*, aerodynamic particle size).

The eco-efficiencies associated with the processes described above are expected to be significant. As with the dismantling facilities however, the above aspects have been excluded from this analysis as a consequence of the lack of readily available data, time constraints, and limitations in the scope of this research. These processes should, however, be reviewed as part of future research to assess the significance of their impacts and to see how they relate proportionally to overall site impacts.

The contributed shredding process data represents a typical one-year operating period (2004 shredding data) and as illustrated in Figure 13, includes:

1) mass flows of shredder feed materials:
    a. ELVs; and
    b. other oversized metals-rich scrap;
2) mass flows of shredder products and wastes:
    a. ferrous metals;
    b. non-ferrous residue; and
    c. shredder residue;
3) energy and water consumed;
4) air emission rates; and
5) process waste water generated.

The collection of data for developing the LCI of the shredding process was straightforward, compared to data collection for the dismantling LCI; the data acquisition from the participating shredding facility was less intensive and required fewer iterations. A comprehensive data set was provided by the industry participant in spreadsheet format that helped render data manipulation and analysis more efficient.

6 VEOL LCI DEVELOPMENT- DATA ANALYSIS

6.1 Dismantling Process LCI

Table 14 summarizes the energy and materials usage and the materials and environmental releases identified for the dismantling process. The usage and release criteria are expressed based on the functional units of per tonne of ELVs retired and processed and per tonne ELVs and COREs processed.

To construct the dismantling LCI, the operating and production data from one dismantler was used, and supplemented with data from other sources to fill in data gaps.

Table 14 Summary of LCI system inputs and outputs for the dismantling process

System Inputs and Outputs				Criteria	Per tonne of ELVs processed (Core Parts Excluded)	% Weight of ELVs processed (Core Parts Excluded)	Per tonne of ELVs & CORES processed	% Weight of ELVs & CORES processed
Inputs	ELVs	Total		kg	1000.0	100.0%	1000.0	100.0%
		LSELVs		kg	867.6	86.8%	866.8	86.7%
		HSELVs		kg	132.4	13.2%	132.2	13.2%
	CORE Parts			kg	----	----	0.97	0.1%
	Electrical Energy			kW-hr	23.1	----	----	----
Outputs	*Parts for Reuse*	Total		kg	57.0	5.7%	57.2	5.7%
		From LSELVs		kg	8.1	0.8%	8.1	0.8%
		From HSELVs		kg	48.9	4.9%	48.9	4.9%
		CORE Parts		kg	----	----	0.2	0.02%
	Parts for Remanufacturing	From HSELVs & CORE Parts		kg	1.2	0.12%	1.2	0.1%
	Parts for Recycling	Total		kg	39.1	3.9%	39.1	3.9%
		From LSELVs		kg	34.3	3.4%	34.2	3.4%
		From HSELVs		kg	4.9	0.5%	4.9	0.5%
	Recovered Fluids	Total		kg	19.0	1.9%	19.0	1.9%
		Directed for Reuse		kg	13.8	1.4%	13.8	1.4%
		Directed for Recycling		kg	5.3	0.5%	5.3	0.5%
	Parts Deleted or Purged from Inventory			kg	3.9	0.4%	3.9	0.4%
	ELV Hulks and Parts Shipped for *Shredding*			kg	883.7	88.37%	883.6	88.4%
	Air Emissions	From Electrical Power Generation (including 7% transmission & distribution losses)	CO_2	kg	6.9	----	----	----
			SO_2	g	25.9	----	----	----
			NO_x (as NO_2)	g	8.9	----	----	----

6.1.1 Dismantling Process Inputs

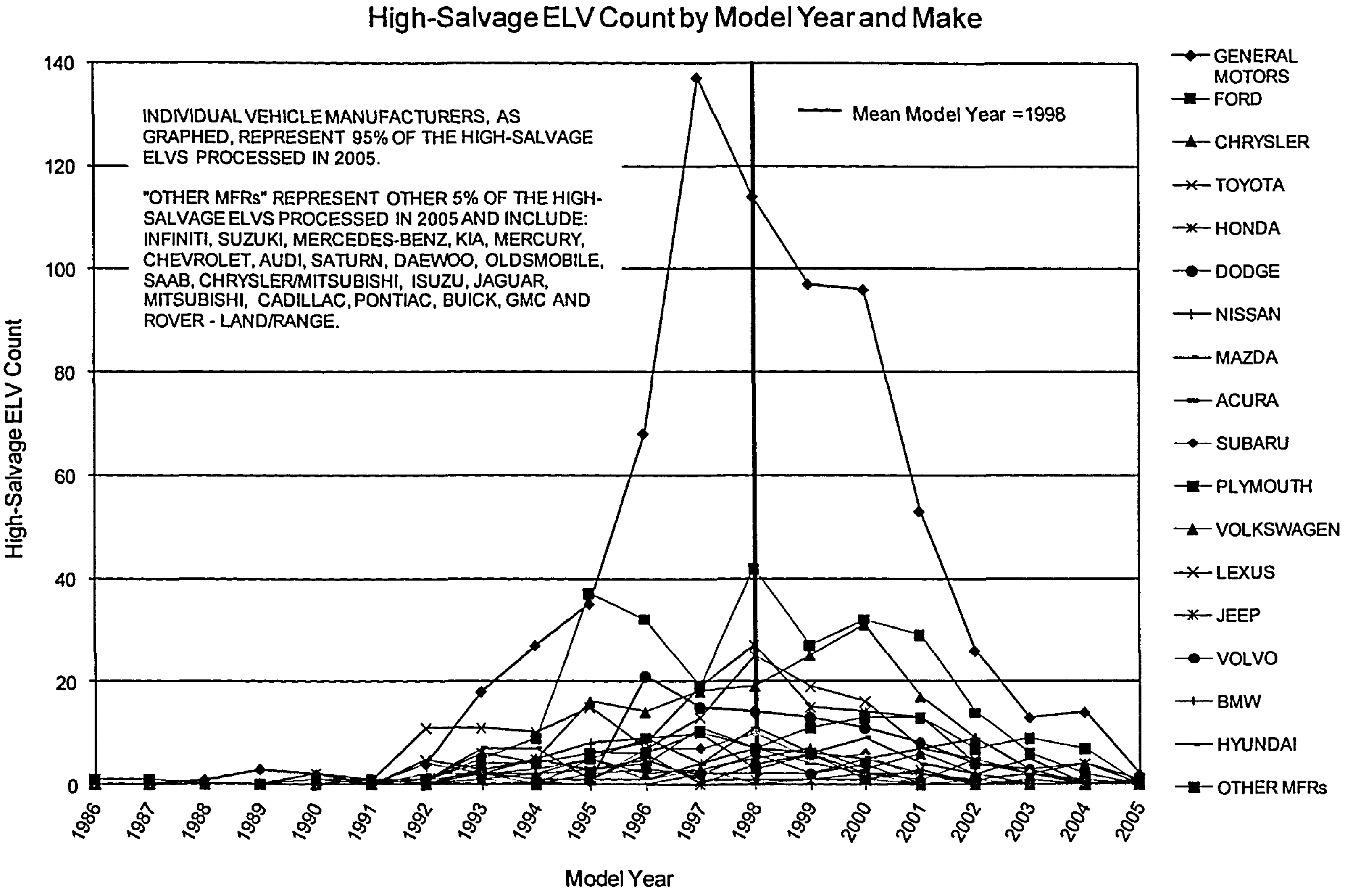
The inputs to the system - "high-salvage" ELVs (HSELVs) and "low-salvage" ELVs (LSELVs), and electrical energy - are calculated based on contributed operating and production data. (see Appendix D, Calculation Methodology). Due to data confidentiality and non-disclosure agreements, the raw data is not included in the thesis.

6.1.1.1 HSELVs and LSELVs Received and Processed

The ELV inputs are based on ELV count data for both the high-salvage and low-salvage ELVs received and processed during one operating year (2005). The ELV count data was sorted by vehicle make, model, and model year. Figures 14 and 15, respectively, present high-salvage ELV counts aggregated and plotted by vehicle make and model year, and for all makes and models combined. Figures 16 and 17, respectively, present low-salvage ELV counts, aggregated and plotted by vehicle make and model year, and for all makes and models combined. In 2005, the HSELVs represented 37 different vehicle manufacturers and 213 different vehicle models, and ranged from 1986 to 2005 model years. LSELVs represented 49 different vehicle manufacturers, 240 different vehicle models and, ranged from 1963 to 2004 model years, with the exception of one 1947 vehicle.

The mean model year was calculated for the HSELVs and for the LSELVs, for all makes combined. The mean model year for all HSELVs combined is 1998, representing an average age of 7 years for the HSELVs processed in 2005. The mean model year for all LSELVs combined is 1990, representing an average age of 15 years for the LSELVs processed in 2005.

To translate the ELV counts into mass flows, representative curb weights were applied to the ELV counts. The curb weight is the "weight of a production car that is ready for the road, with fluid reservoirs (including fuel tank) full and all normal equipment in place but without driver, passengers, or cargo" [Dinkel, 2000].



High-Salvage ELV Count by Model Year and Make

INDIVIDUAL VEHICLE MANUFACTURERS, AS GRAPHED, REPRESENT 95% OF THE HIGH-SALVAGE ELVS PROCESSED IN 2005.

"OTHER MFRs" REPRESENT OTHER 5% OF THE HIGH-SALVAGE ELVS PROCESSED IN 2005 AND INCLUDE: INFINITI, SUZUKI, MERCEDES-BENZ, KIA, MERCURY, CHEVROLET, AUDI, SATURN, DAEWOO, OLDSMOBILE, SAAB, CHRYSLER/MITSUBISHI, ISUZU, JAGUAR, MITSUBISHI, CADILLAC, PONTIAC, BUICK, GMC AND ROVER - LAND/RANGE.

Figure 14 HSELV counts (for HSELVs processed in 2005) aggregated and plotted by vehicle make and model year.

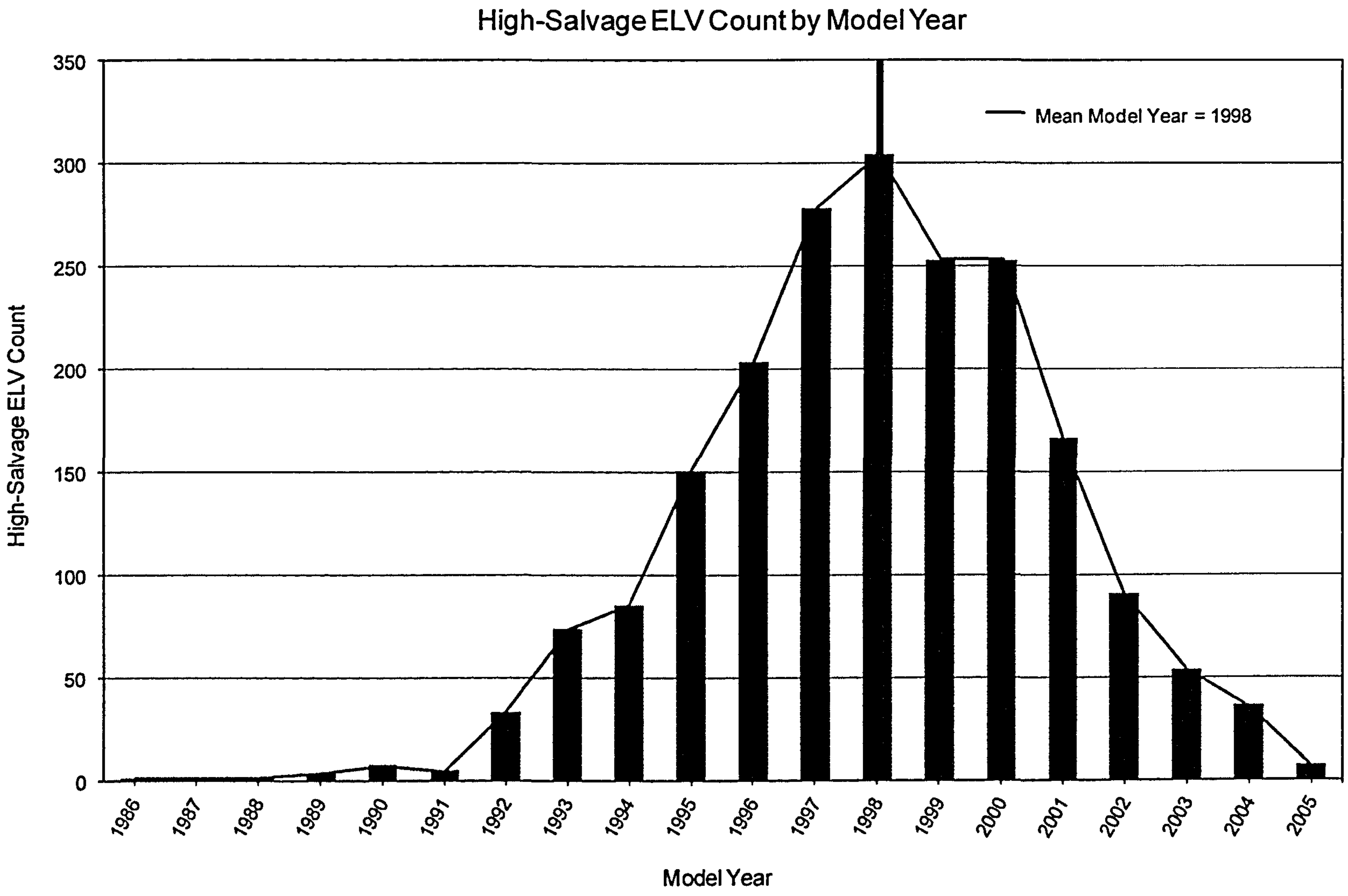
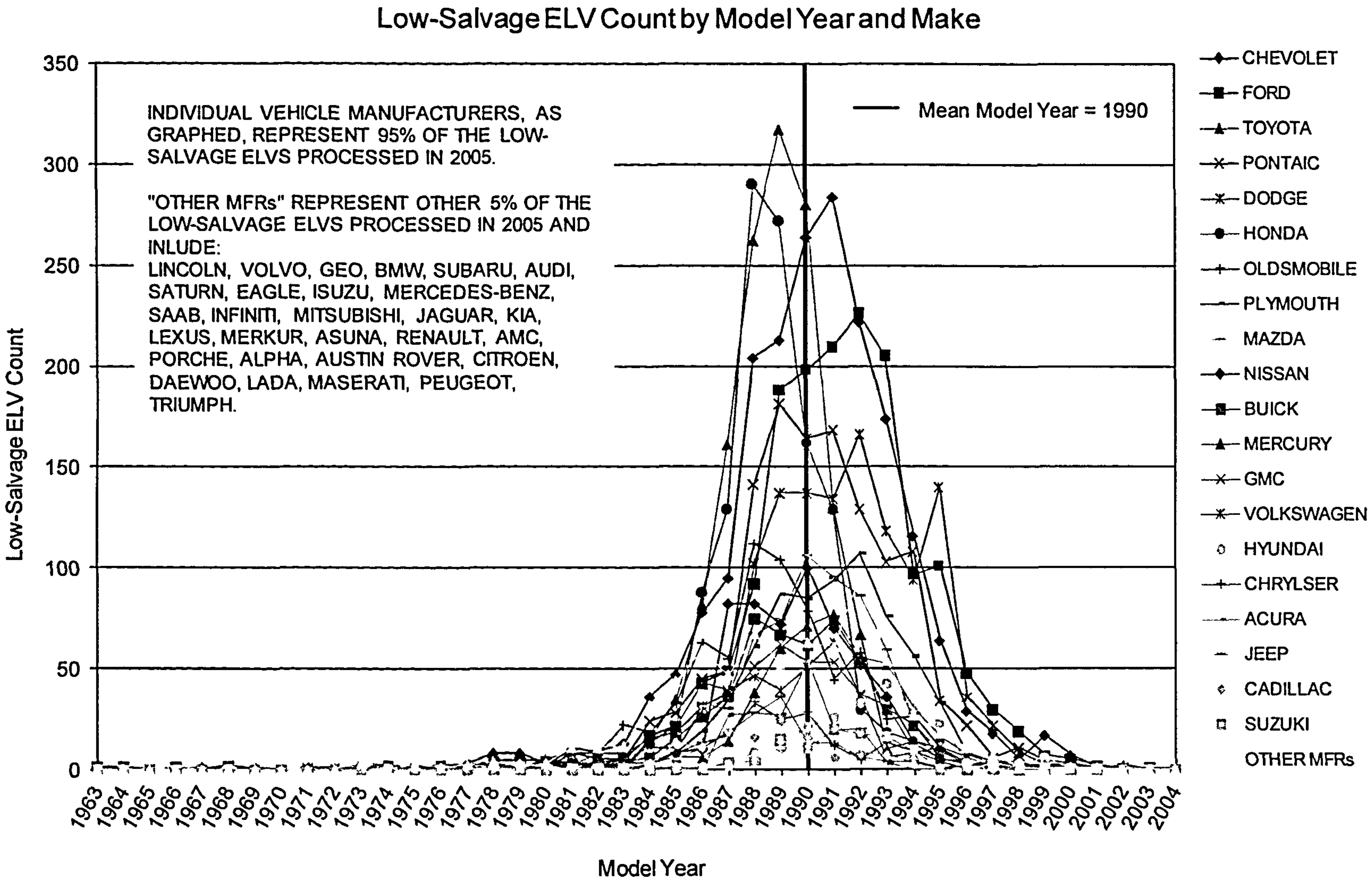


Figure 15 HSELV counts (for HSELVs processed in 2005) aggregated and plotted by vehicle model year.



INDIVIDUAL VEHICLE MANUFACTURERS, AS GRAPHED, REPRESENT 95% OF THE LOW-SALVAGE ELVS PROCESSED IN 2005.

"OTHER MFRs" REPRESENT OTHER 5% OF THE LOW-SALVAGE ELVS PROCESSED IN 2005 AND INLUDE:
LINCOLN, VOLVO, GEO, BMW, SUBARU, AUDI, SATURN, EAGLE, ISUZU, MERCEDES-BENZ, SAAB, INFINITI, MITSUBISHI, JAGUAR, KIA, LEXUS, MERKUR, ASUNA, RENAULT, AMC, PORCHE, ALPHA, AUSTIN ROVER, CITROEN, DAEWOO, LADA, MASERATI, PEUGEOT, TRIUMPH.

Figure 16 LSELV counts (for LSELVs processed in 2005) aggregated and plotted by vehicle make and model year.

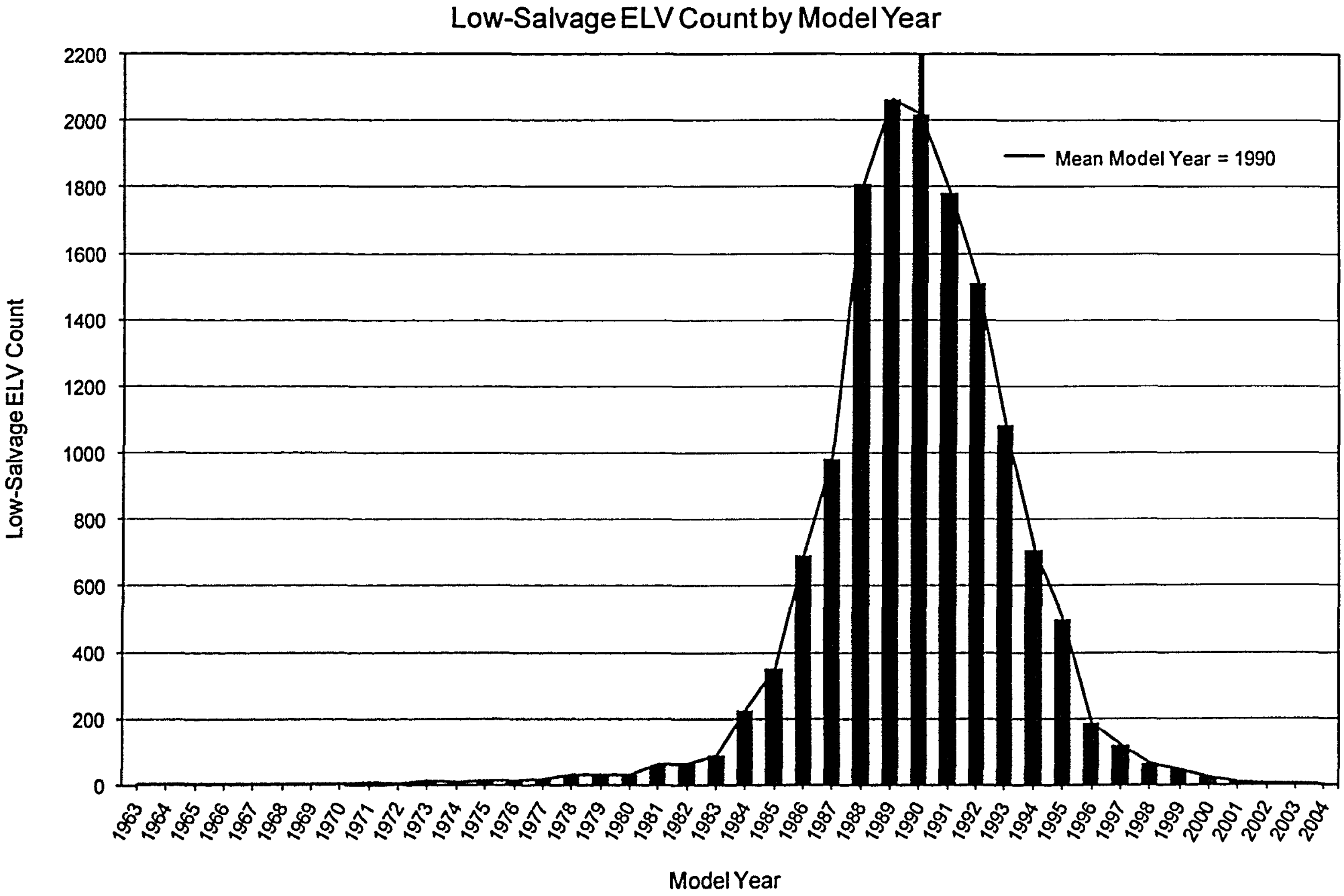


Figure 17 LSELV counts (for LSELVs processed in 2005) aggregated and plotted by vehicle model year.

Curb weight data was most readily available from sources on the World Wide Web, principally from the HowStuffWorks' (HSW) Consumer Guide Automotive used cars research website (http://consumerguideauto.howstuffworks.com/consumer-guide-used-car-search.htm) [HSW, 2008] and the MSN Autos (MSNA) Used Car Research website (http://autos.msn.com/home/used_research.aspx) [MSNA, 2008]. Curb weights vary with vehicle body/trim styles because of the different choices of equipment options (*e.g.,* 6-cyclinder versus 8-cylinder engine), different body styles (*e.g.,* 2-door coupe versus 4-door sedan) or different drivetrains (*e.g.,* 2-wheel versus 4-wheel drive; manual versus automatic transmission) that can be selected by the consumer.

Since vehicle body/trim styling were not known for the majority of ELVs received and processed (only vehicle model), representative curb weights of several body styles were applied to each vehicle and averaged to establish an estimated mean curb weight for each vehicle, by vehicle model and model year.

Vehicle curb weights were available for a variety of different body/trim styles, including:

- 2-door coupe
- 3-door coupe
- 2-door convertible
- 2-door hatchback
- 2-door wagon
- 4-door coupe
- 4-door sedan
- 4-door wagon
- 4-door hatchback
- 2-door van
- 3-door van
- 4-door van
- cargo van
- reg. cab
- reg. cab long bed
- reg. cab short bed
- ext. (extended) cab
- ext. cab long bed
- ext. cab short bed
- crew cab
- crew cab long bed
- crew cab short bed

In addition to curb weights, a vehicle size class was assigned to each model of vehicle. Vehicle class information was obtained from the Oak Ridge National Laboratory (ORNL) fueleconomy.gov web site [ORNL, 2008] and Natural Resources Canada (NRC) Office of Energy Efficiency (OEE) Fuel Consumption Ratings website [NRC, 2008]. Table 15 summarizes the vehicle size classes used in Canada and the United States [NRC, 2008; ORNL, 2008].

Table 15 Summary of vehicle size classes used in the United States and Canada

<table>
<tr><th colspan="8">Vehicle Size Classes</th></tr>
<tr><th colspan="2" rowspan="2">Canada</th><th colspan="6">United States</th></tr>
<tr><th colspan="3">Cars</th><th colspan="4">Trucks</th></tr>
<tr><th>Class</th><th>Passenger & Cargo Volume</th><th colspan="2">Class</th><th>Passenger & Cargo Volume</th><th colspan="2">Class</th><th colspan="2">Gross Vehicle Weight Rating (GVWR)*</th></tr>
<tr><td>Two seater (T)</td><td>--</td><td colspan="2">Two-Seaters</td><td>Any cars designed to seat only two adults</td><td rowspan="3">Pickup Trucks</td><td>Applicable Model Year</td><td>≤ 2007</td><td>≥ 2008</td></tr>
<tr><td>Subcompact (S)</td><td>< 2,830 L (100 cu. ft.)</td><td rowspan="5">Sedans</td><td>Minicompact</td><td>< 85 cu. ft. (2400 L)</td><td>Small</td><td>< 4,500 lbs. (2040 kg.)</td><td>< 6,000 lbs. (2700 kg)</td></tr>
<tr><td>Compact (C)</td><td>2,830 L to 3,115 L (100 to 110 cu. ft.)</td><td>Subcompact</td><td>85 to 99 cu. ft. (2400 to 2800 L)</td><td>Standard</td><td>4,500 to 8,500 lbs. (2040 to 3850 kg)</td><td>6,000 to 8,500 lbs. (2700 to 3850 kg)</td></tr>
<tr><td>Mid size (M)</td><td>3,115 L to 3,400 L (110 to 120 cu. ft.)</td><td>Compact</td><td>100 to 109 cu. ft. (2800 to 3100 L)</td><td rowspan="2">Vans</td><td>Passenger</td><td colspan="2">< 8,500 lbs. (3850 kg)</td></tr>
<tr><td>Full size (L)</td><td>> 3,400 L (120 cu. ft.)</td><td>Mid-Size</td><td>110 to 119 cu. ft. (3100 to 3400 L)</td><td>Cargo</td><td colspan="2">< 8,500 lbs. (3850 kg)</td></tr>
<tr><td>Station Wagon (W)</td><td>--</td><td>Large</td><td>≥120 cu. ft. (3400 L)</td><td colspan="2">Minivans</td><td colspan="2">< 8,500 lbs. (3850 kg)</td></tr>
<tr><td>Pickup truck (PU)</td><td>--</td><td rowspan="3">Station Wagons</td><td>Small</td><td><130 cu. ft. (3700 L)</td><td colspan="2">Sport Utility Vehicles (SUVs)</td><td colspan="2">< 8,500 lbs. (3850 kg)</td></tr>
<tr><td>Special purpose (SP)</td><td>--</td><td>Mid-Size</td><td>130 to 159 cu. ft. (3700 to 4500 L)</td><td colspan="2">Special Purpose Vehicles</td><td colspan="2">< 8,500 lbs. (3850 kg)</td></tr>
<tr><td>Van (V)</td><td>--</td><td>Large</td><td>≥160 cu. ft. (4500 L)</td><td colspan="4"></td></tr>
<tr><td>Car (1995-1999) (CC)</td><td>--</td><td colspan="7">* Gross Vehicle Weight Rating (GVWR) = truck weight plus carrying capacity.</td></tr>
</table>

In general, passenger cars in Canada and the U.S. are classified by their passenger- and cargo-carrying capacities. Trucks in the U.S. are classified according to their Gross Vehicle Weight Rating (GVWR), which is the truck weight plus carrying capacity. The compact, mid size and full size vehicle classifications used in Canada are comparable to those used the United States. The U.S. minicompact and subcompact size classes are covered under Canada's subcompact size class. In the U.S. station wagons are classified into three size classes according to interior volumetric capacities, but in Canada they are lumped into one size class. Unlike the U.S., the special purpose vehicle class in Canada includes special utility vehicles (SUVs).

Because of the limited amount of information available for each HSELV and LSELV – only make, model and model year – it was decided to use a simplified vehicle size class scheme, paralleling the Canadian vehicle size classification system. Table 16 summarizes the vehicle size classification scheme that has been adopted for the HSELVs and LSELVs, as well as the vehicle body styles that have been included in each of the size classes as a consequence of the curb weights applied to each vehicle model. For each of the subcompact, compact, midsize or large size vehicle classes, all available body styles for a particular vehicle model, including station wagon and hatchback body styles, were included in a single size class. The one exception is the case of a vehicle that is available in a station wagon body style only, such as Toyota Matrix. These vehicles were accounted for in the station wagon size class. This size classification method allowed the 2,003 HSELVs and the 14,882 LSELVs entering the dismantling process to be evaluated by weight and size class.

As previously mentioned, an estimated curb weight for each vehicle was calculated as the mean of multiple curb weights representing several body styles for each vehicle, by vehicle model and model year. The mean ELV curb weight data has been aggregated and average mean ELV curb weights calculated by vehicle size class for both the HSELVs and LSELVs. Tables 17 and 18, respectively, summarize the estimated mean HSELV and LSELV curb weight maxima, minima, and averages by vehicle size class. This data is also illustrated in Figures 18 and 19. Approximately 3.5% (505) of the 14,882 LSELVs processed in 2005 were grouped into the category of "Unknown" vehicle size class because only vehicle make and/or vehicle model year were known, or they were simply identified as scrap vehicles (37 vehicles out of the 505). For the LSELVs of a "known" vehicle make, (*e.g.,* Acura) and model year, but unknown vehicle model, the curb weight estimates were calculated by model year by

Table 16 Summary of the vehicle size classes applied to the HSELVs and LSELVs and body/trim styles grouped into each class

Body/Trim Styles	Vehicle Size Classes								
	Two seater	Sub-compact	Compact	Midsize	Largesize	Station Wagon	Van	Special Purpose	Pickup
2-door coupe		X	X	X	X				
3-door coupe			X						
2-door convertible	X	X	X	X				X	
2-door hatchback		X	X	X					
2-door wagon								X	
4-door coupe			X						
4-door sedan		X	X	X	X			X	
4-door wagon		X	X	X		X		X	
4-door hatchback			X	X					
2-door van									
3-door van							X	X	
4-door van							X	X	
cargo van							X		
reg. cab									X
reg. cab long bed									X
reg. cab short bed									X
ext. cab									X
ext. cab long bed									X
ext. cab short bed									X
crew cab								X	X
crew cab long bed									X
crew cab short bed									X

Table 17 Estimated HSELV curb weight maxima, minima, and averages summarized by vehicle size class

Vehicle Class	Estimated HSELV Curb Weights (kg)			Standard Deviation	Mean Curb Weight Count Used in Calculation of Average Mean Curb Weight	Coefficient of Variation (%)
	Maximum	Minimum	Average			
Two seater	1055.1	1055.1	1055.1	—	2	—
Subcompact	1599.8	850.0	1178.6	187.0	108	15.9%
Compact	1925.7	918.5	1258.4	156.2	495	12.4%
Midsize	1930.1	1269.2	1473.1	126.6	519	8.6%
Largesize	1930.1	1480.1	1634.8	113.5	170	6.9%
Station Wagon	1779.9	1334.9	1596.5	—	3	—
Van	2742.0	1499.1	1760.5	194.9	470	11.1%
Special Purpose	2277.1	1329.0	1769.6	242.4	170	13.7%
Pickup	2445.0	1211.1	1823.7	220.4	66	12.1%

Table 18 Estimated LSELV curb weight maxima, minima, and averages summarized by vehicle size class

Vehicle Class	Estimated LSELV Curb Weights (kg)			Standard Deviation	Mean Curb Weight Count Used in Calculation of Average Curb Weight	Coefficient of Variation (%)
	Maximum	Minimum	Average			
Two seater	1588.0	869.7	1141.7	206.5	52	18.1
Subcompact	1824.9	675.0	1078.9	167.4	2385	15.5
Compact	2148.5	920.8	1191.2	122.4	4976	10.3
Midsize	2148.5	999.7	1364.9	126.8	2834	9.3
Largesize	2148.5	1313.8	1590.9	110.3	1107	6.9
Station Wagon	1968.2	1113.6	1443.7	254.2	43	17.6
Van	2536.7	1079.9	1709.9	188.7	2143	11.0
Special Purpose	2455.0	957.3	1620.1	345.0	440	21.3
Pickup	2414.0	1233.4	1658.4	307.2	397	18.5
Unknown	2148.5	1032.8	1372.7	170.8	505	12.4

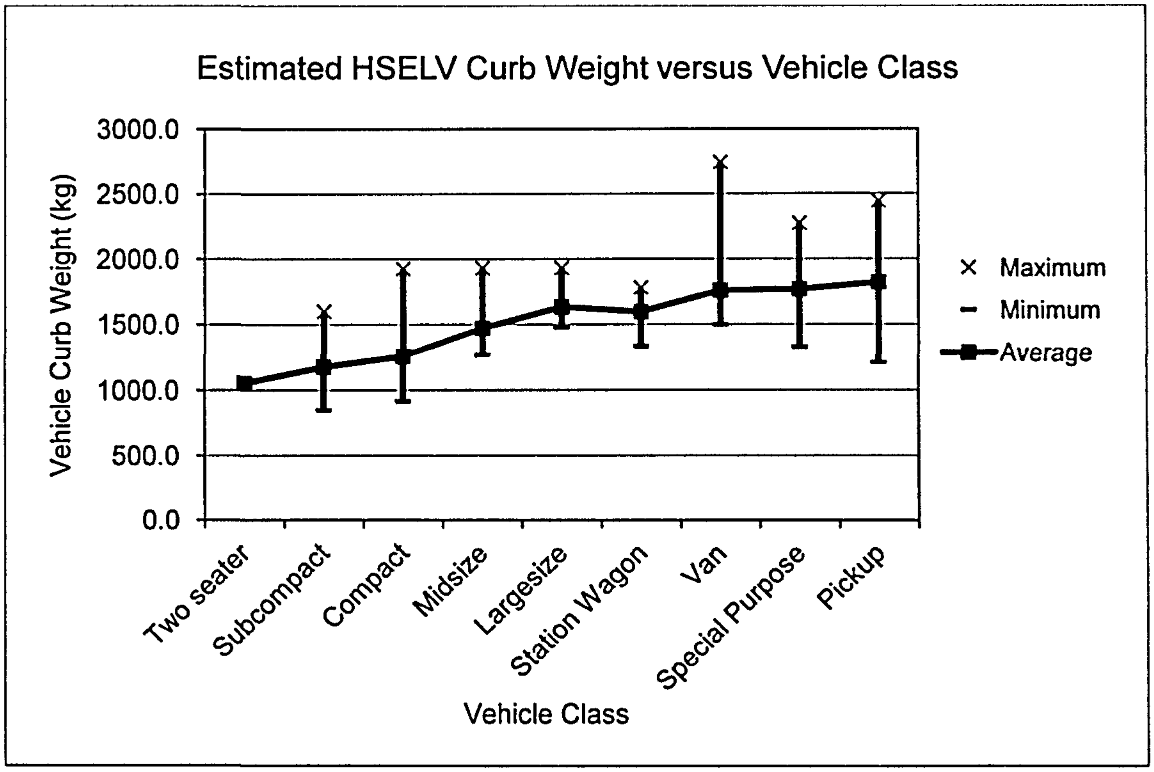


Figure 18 HSELV curb weight maxima, minima, and averages plotted by vehicle size class.

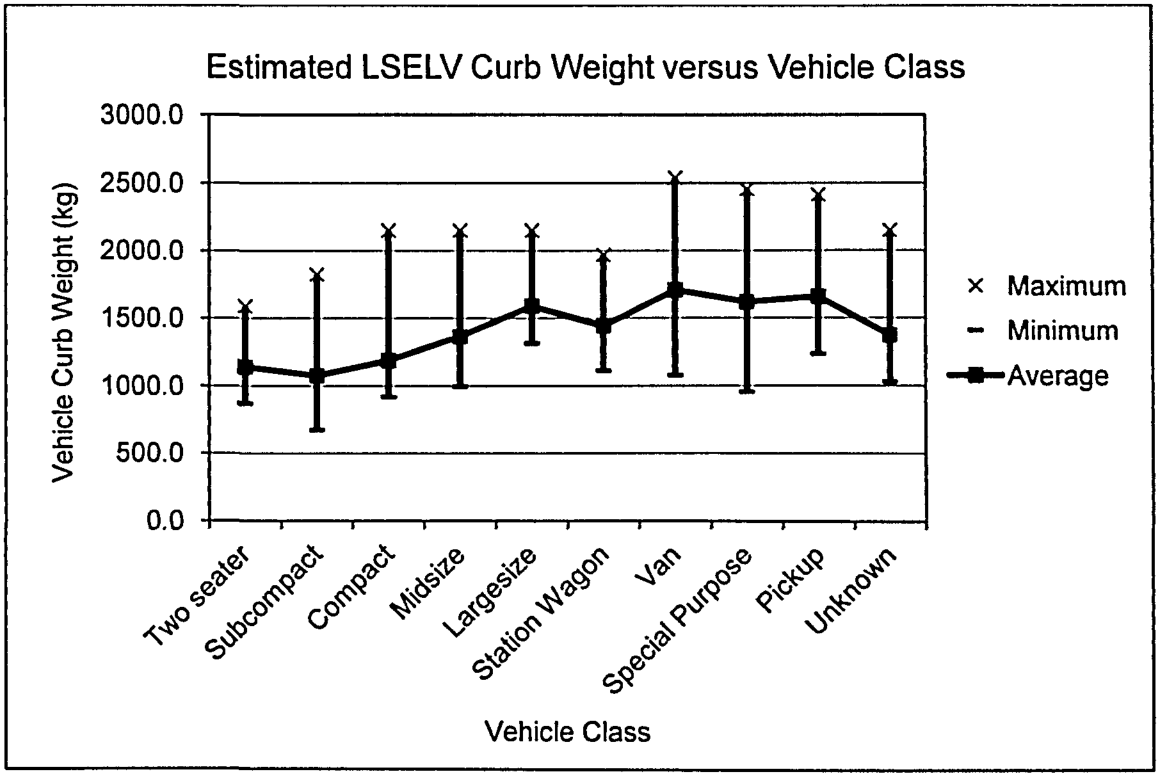


Figure 19 HSELV curb weight maxima, minima, and averages plotted by vehicle size class.

averaging the curb weights identified and used for the known vehicle models for that specific vehicle make and model year. For example, the vehicle curb weights of all the 1990 "known" Acura models were averaged to estimate a curb weight for a 1990 "unknown" Acura vehicle model. For the vehicles identified as scrap, curb weights were estimated by averaging the weights of all the vehicles of known make, model and model year. Of the ELVs processed in 2005, an HSELV averaged 1522 kg and an LSELV averaged 1343 kg.

Using the average mean HSELV and LSELV curb weight estimates and actual vehicle counts by size class, the proportions of HSELVs and LSELVs entering the dismantling process were calculated on a mass basis and are presented in Table 19. Figures 20 and 21, respectively, compare the weight distribution and unit volume distribution of HSELVs to LSELVs by vehicle size class. Currently, significantly more subcompact and compact vehicles are managed as LSELVs rather than as HSELVs, while a greater proportion of midsize and special purpose vehicles and vans are managed as HSELVs. The dismantler may select midsize vehicles, special purpose vehicles and vans to be managed as HSELVs because their recoverable parts are currently of higher value and/or are in greater demand compared to parts from smaller

Table 19 ELVs entering the dismantling process by mass and volume

Vehicle Class	ELVs Entering the Dismantling Process by Vehicle Class, by Volume and Estimated Mass					
	HSELVs			LSELVs		
	% Unit Volume	kg	%wgt	% Unit Volume	kg	%wgt
Two seater	0.1%	2,110	0.1%	0.3%	59,370	0.3%
Subcompact	5.4%	127,288	4.2%	16.0%	2,573,066	12.9%
Compact	24.7%	622,911	20.4%	33.4%	5,927,320	29.7%
Midsize	25.9%	764,533	25.1%	19.0%	3,868,116	19.4%
Largesize	8.5%	277,923	9.1%	7.4%	1,761,125	8.8%
Station Wagon	0.1%	4,790	0.2%	0.3%	62,077	0.3%
Van	23.5%	827,413	27.1%	14.4%	3,664,332	18.3%
Special Purpose	8.5%	300,840	9.9%	3.0%	712,855	3.6%
Pickup	3.3%	120,366	3.9%	2.7%	658,370	3.3%
Unknown				3.4%	693,218	3.5%
Totals =	100.0%	3,048,174	100.0%	100.0%	19,979,849	100.0%

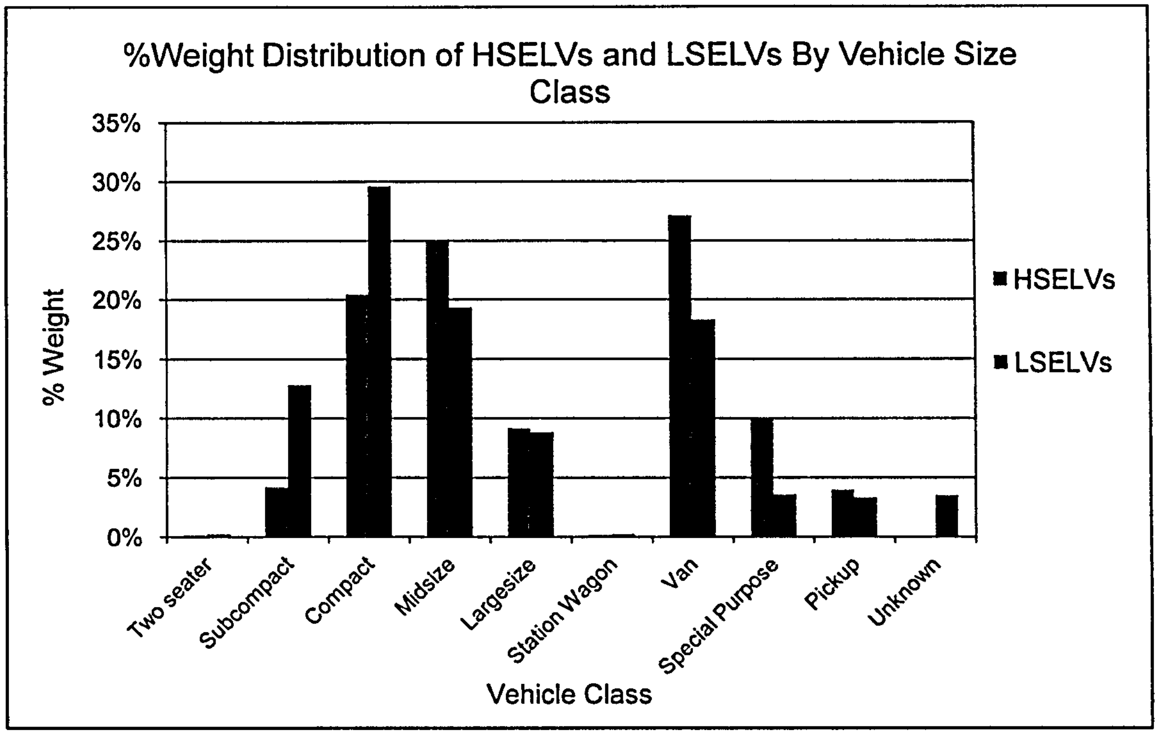


Figure 20 Comparison of the weight proportions of HSELVs and LSELVs entering the dismantling system, by vehicle size class.

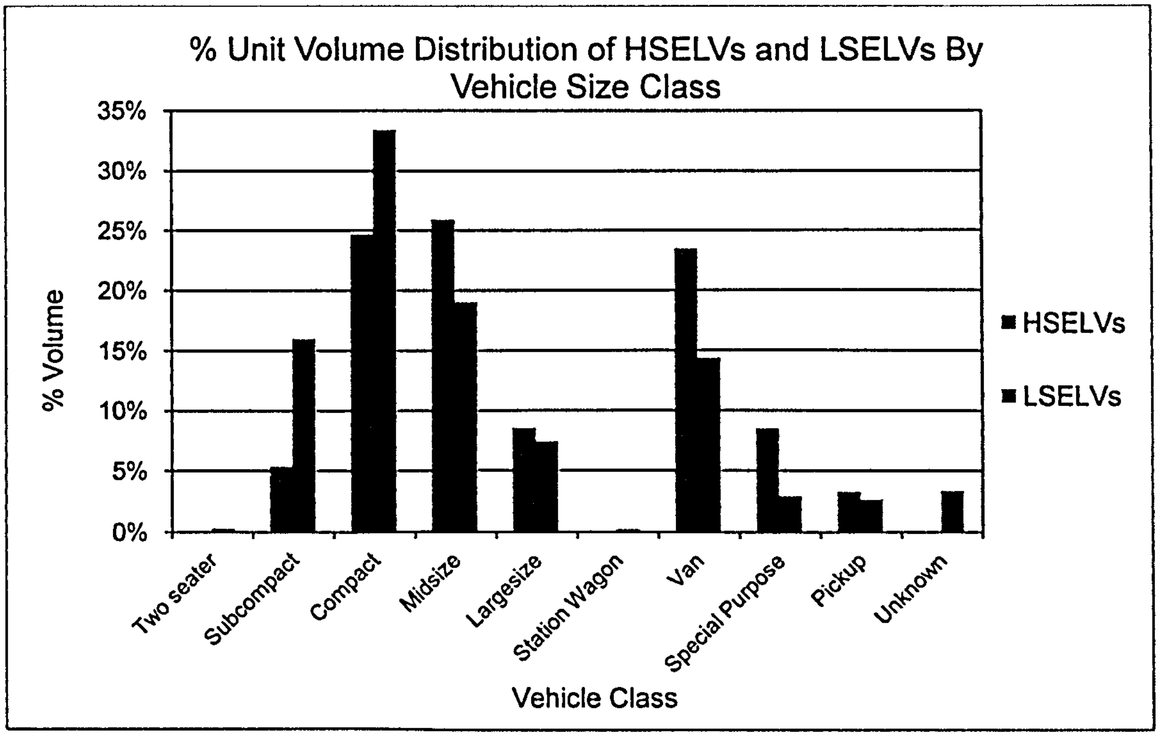


Figure 21 Comparison of the unit volume proportions of HSELVs and LSELVs entering the dismantling system, by vehicle size class.

vehicle types. Additional data analysis would be required to confirm if market reasons explain this observed trend, or if there are other issues that influence the dismantler's approach to salvaging vehicles.

Given the current "green" trend and economic crisis, it would not be surprising if over the next few years the perceived parts recovery practices of several years ago (about year 2005) reverses with a greater proportion of subcompact and compact vehicles being managed as HSELVs than LSELVs. As larger vehicles fall out of favour for environmental and/or economic reasons with consumers, it is possible that more large size vehicles, special purpose vehicles, and vans will be considered LSELVs.

Based on the estimated masses of HSELVs and LSELVs entering the dismantling process, 132.4 kg and 867.6 kg of HSELVs and LSELVs, respectively, are processed per tonne of ELVs retired (see Appendix D for Calculation Methodology).

6.1.1.2 Cash-On-Return (CORE) Parts

Table 20 summarizes the CORE parts received in 2005 for return of a CORE deposit or charge. The CORE charges are applied on particular HSELV part types to encourage customers to offer their old part (of the same part type) in exchange for the return of the CORE charge, when they purchase the "new" used replacement part. This allows the dismantler to obtain additional parts that may have resale value. Some CORE parts may, subsequently, be sold for reuse. Some may be sold for remanufacturing along with remanufacturable parts recovered from the HSELVs. CORE parts not suitable for reuse or remanufacturing will be directed for recycling, along with the ELV hulks shipped for shredding.

Table 20 Summary of CORE parts received

	Weight			
	kg/tonne HSELV Parts Sold for Reuse	% Wgt. of HSELV Parts Sold for Reuse	kg/tonne ELVs and CORE Parts Processed	% Wgt. of ELVs and CORE Parts Processed
CORE Parts Received	19.87	1.99%	0.97	0.10%

By weight, CORE parts represent 2% of the HSELV parts sold for reuse, but less than 1% of the combined weight of the ELVs and CORE parts received. Figures 22, 23, and 24 illustrate the estimated weight proportions of the 62 part types received as CORE parts (in kg/tonne ELVs and CORE parts processed). The data for the 62 part types is

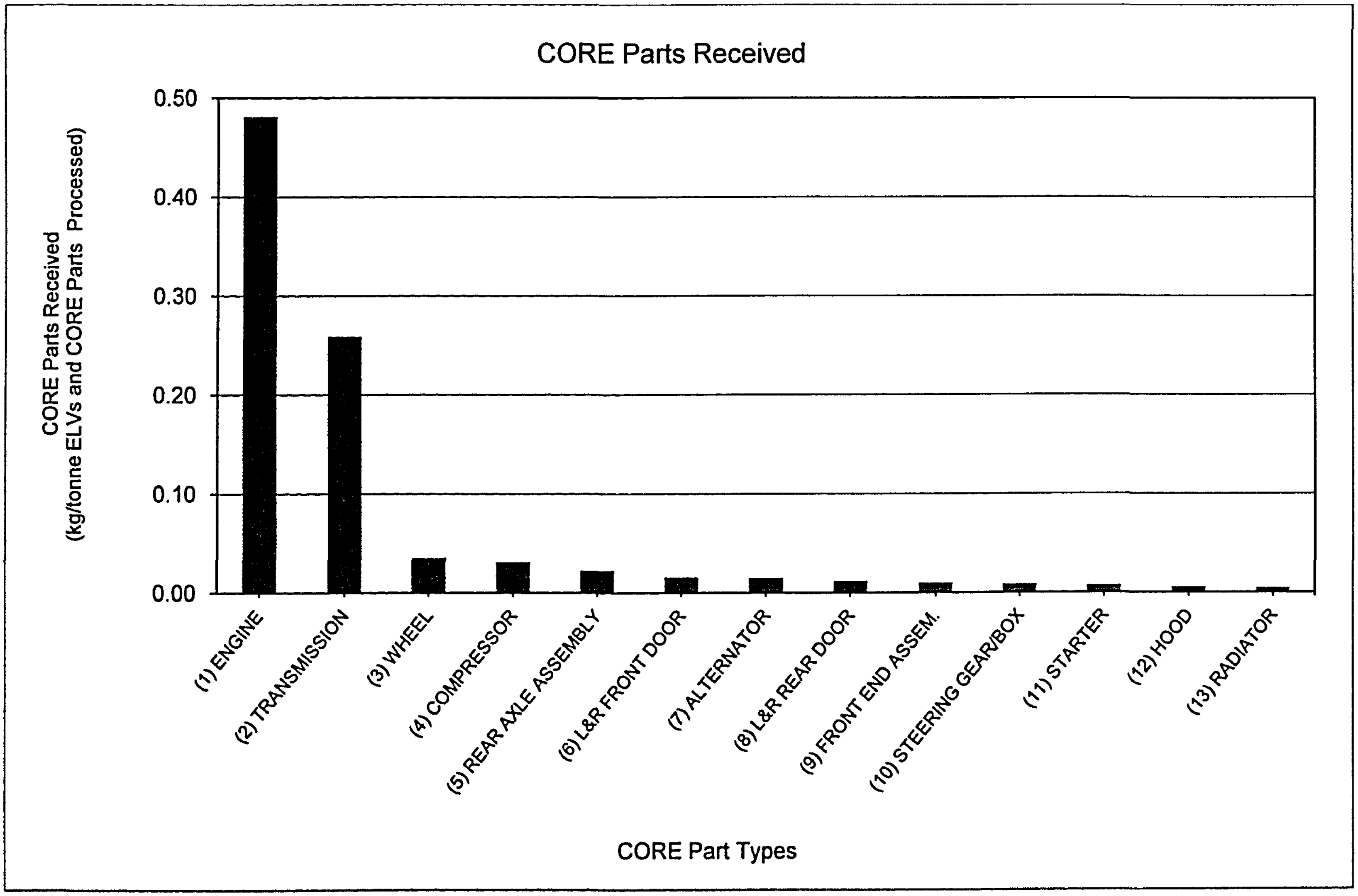


Figure 22 CORE parts received, with CORE Part Types (1) to (13) presented in order of decreasing weight proportion.

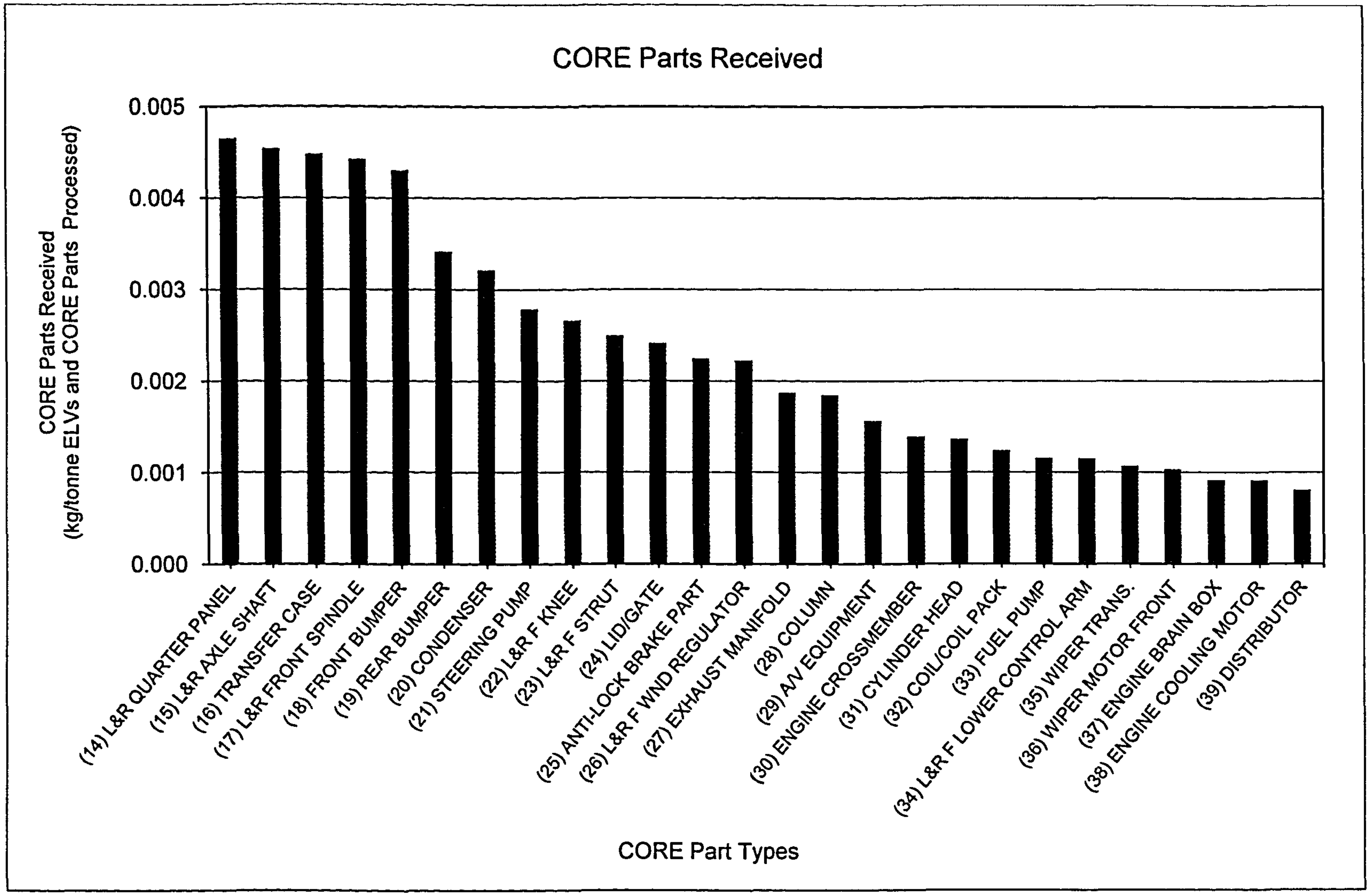


Figure 23 CORE parts received, with CORE Part Types (14) to (39) presented in order of decreasing weight proportion.

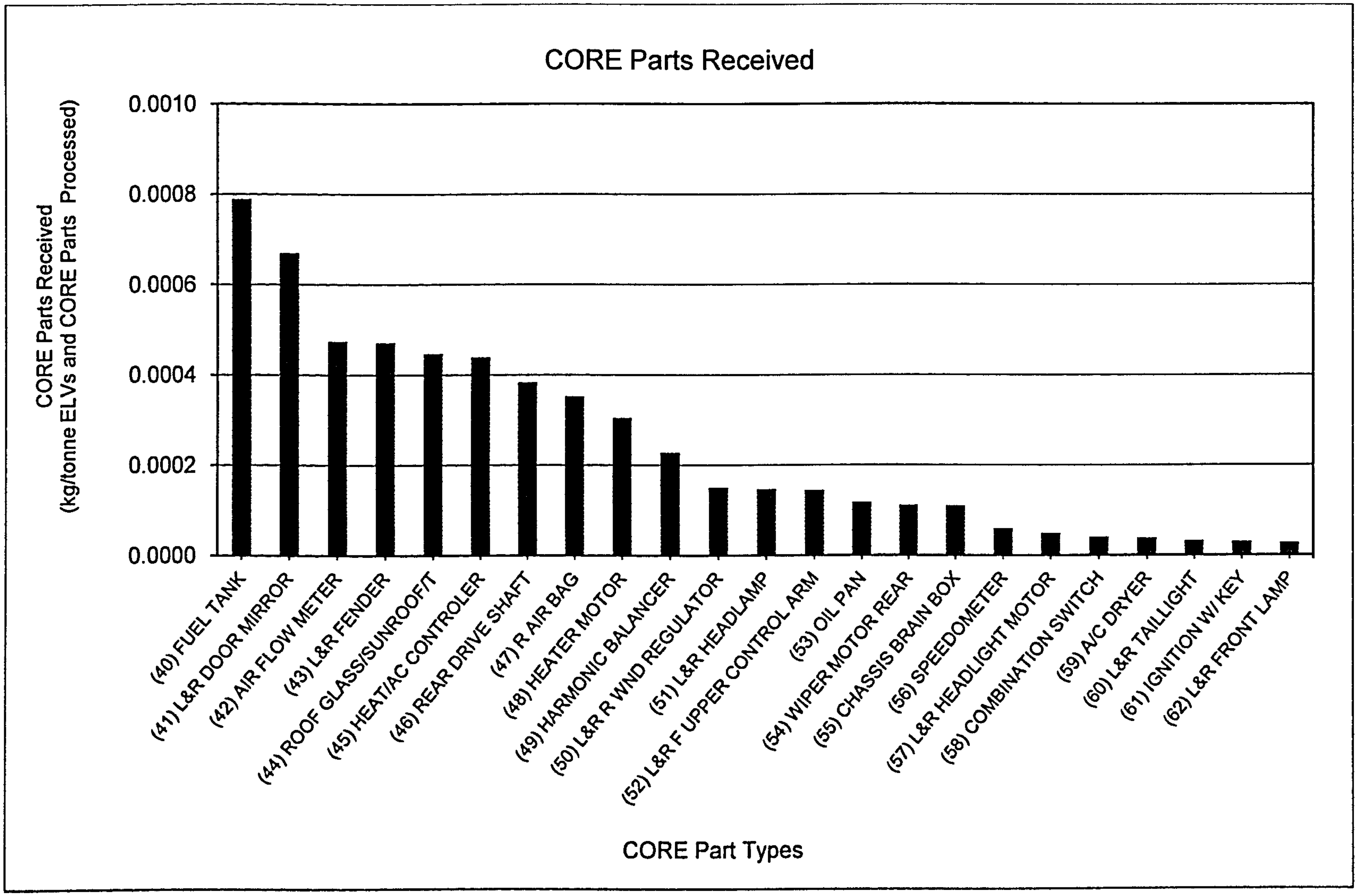


Figure 24 CORE parts received, with CORE Part Types (40) to (62) presented in order of decreasing weight proportion.

plotted in order of decreasing weight proportion. The first 13 part types plotted in Figure 22 represent 93% by weight of all the CORE parts received in 2005. The mass proportions of CORE parts received were calculated using:

1) the CORE part counts;
2) the part weights for the parts collected from the Parts Mass Study vehicles - the compact sedan ('97 Neon), the minivan ('96 Voyager) and the SUV ('94 Explorer);
3) the percent unit volume proportions of HSELVs entering the dismantling process by vehicle size class;
4) the numbers of HSELVs entering the process; and
5) assuming a CORE part that is received in exchange for a CORE charge credit is of the same make and model as the HSELV part that was sold as a replacement.

The CORE part counts and the vehicle part weights from the Parts Mass Study were applied to the unit volume percentages of vehicles in the different vehicle size classes to estimate the mass of the CORE parts received distributed over the different HSELV size classes. For example, the mass of AC compressors received as CORE parts was estimated according to the following formula.

$$\begin{aligned}
&\text{Total Parts Mass (kg) of AC Compressors recieved as CORE parts}, TPM_{AC\ Compressor,COREs} = \\
&= PtCt_{Compressor,COREs}\big[PtWt_{Compressor,Neon}\big(\%VVeh_{HSELVs,T} + \%VVeh_{HSELVs,S} + \%VVeh_{HSELVs,C} \\
&\quad + \%VVeh_{HSELVs,M}\big) \\
&\quad + PtWt_{Compressor,Voyager}\big(\%VVeh_{HSELVs,L} + \%VVeh_{HSELVs,W} + \%VVeh_{HSELVs,V}\big) \\
&\quad + PtWt_{Compressor,Explorer}\big(\%VVeh_{HSELVs,SP} + \%VVeh_{HSELVs,P}\big)\big] \div 100, \text{where:}
\end{aligned} \tag*{[1]}$$

$PtCt_{Compressor,COREs} = \text{Part Count for AC Compressors recieved as CORE parts};$

$PtWt_{Compressor,Neon} = \text{Part Weight (kg) for AC Compressor from 1997 Neon};$

$PtWt_{Compressor,Voyager} = \text{Part Weight (kg) for AC Compressor from 1996 Voyager};$

$PtWt_{Compressor,Explorer} = \text{Part Weight (kg) for AC Compressor from 1994 Explorer}$

$\%VVeh_{HSELVs,T} = \%\ \text{Unit Volume HSELVs in Two seater(T) Vehicle Size Class};$

$\%VVeh_{HSELVs,S} = \%\ \text{Unit Volume HSELVs in Subcompact(S) Vehicle Size Class};$

$\%VVeh_{HSELVs,C} = \%\ \text{Unit Volume HSELVs in Compact(C) Vehicle Size Class};$

$\%VVeh_{HSELVs,M} = \%\ \text{Unit Volume HSELVs in Midsize(M) Vehicle Size Class};$

$\%VVeh_{HSELVs,L} = \%\ \text{Unit Volume HSELVs in Largesize(L) Vehicle Size Class};$

$\%VVeh_{HSELVs,W} = \%\ \text{Unit Volume HSELVs in Station Wagon(W) Vehicle Size Class};$

$\%VVeh_{HSELVs,SP} = \%\ \text{Unit Volume HSELVs in Special Purpose(SP) Vehicle Size Class};$

$\%VVeh_{HSELVs,P} = \%\ \text{Unit Volume HSELVs in Pickup(P) Vehicle Size Class}.$

6.1.1.3 Electrical Energy Use

Energy input to the dismantling process is estimated based on the dismantling facility's annual electrical consumption in kW-h, the numbers of HSELVs and LSELVs processed in one year, and the estimated HSELV and LSELV mean weights. The resulting energy consumption of 23.1 kW-h/tonne of ELVs processed accounts for electricity used for operating power tools and equipment used in the dismantling process, such as hoists and compressors, as well as for lighting and office equipment but not for comfort heating. The dismantler that provided the electricity usage data indicated that used oil-fired space heaters are used in their facility (as well as by other dismantlers) for comfort heating.

6.1.2 Dismantling Process Outputs

The outputs from the dismantling system represented in this LCI include:

1) parts recovered from HSELVs and sold for reuse, remanufacturing, or recycling;
2) parts recovered from LSELVs and sold for reuse or recycling;
3) CORE parts sold for reuse or recycling;
4) recovered fluids;
5) HSELV parts deleted from inventory;
6) ELV hulks and parts shipped for shredding; and
7) greenhouse gas (GHG) emissions due to electrical power generation.

6.1.2.1 Parts Recovered and Sold For Reuse

Parts recovered from HSELVs and LSELVs and sold for reuse include at a minimum tires and wheels, un-deployed airbags, batteries and catalytic convertors, as well as other parts having potential resale value. Except for the occasional fuel tank identified for recovery and reuse, most fuel tanks are sacrificed to recover residual fuel. To assess the parts recovered from HSELVs and LSELVs for direct reuse, part count data was used representing one year of HSELV parts sales and 6 months of LSELV parts sales. CORE parts received and sold for reuse were assessed based on part count data representing one year of CORE part sales.

6.1.2.1.1 Reusable Parts from HSELVs

The HSELV parts information includes part type, vehicle make, model and model year, allowing the HSELV part count data to also be sorted, and aggregated, by vehicle make, model, and model year. Figures 25 and 26, respectively, present HSELV part counts aggregated and plotted by vehicle make and model year, and for all makes and models combined. In 2005, the HSELV parts sold for reuse came from vehicles representing 41 different vehicle manufacturers and 214 different vehicle models, and in model years ranging from 1977 to 2006.

Mean model year was calculated for the HSELV parts sold for reuse, for all makes combined. As similarly identified for the HSELVs processed in 2005, the mean model year for the HSELV parts sold for reuse is 1998, representing an average age of 7 years for the HSELVs parts sold in 2005. The similarity of mean model years calculated using the HSELV counts and the HSELV part counts is significant. It implies that, on average, the turnaround time for the recovery and subsequent sale of the parts is very short: in this analysis, the interval is less than 1 year.

If the parts turnaround time had been appreciably longer, then a difference between the mean model years calculated would be expected, with HSELVs parts, on average, being sold from vehicles of earlier model years than the HSELVs currently being received and processed. This would mean that:

$$Mean\ Model\ Year_{HSELV\ Parts\ Sold} < Mean\ Model\ Year_{HSELVs\ Processed}$$

The mass proportions of parts recovered from HSELVs and directed for reuse, were calculated using:

1) the HSELV part counts;
2) the part weights for the parts collected from the Parts Mass Study vehicles - the compact sedan ('97 Neon), the minivan ('96 Voyager) and the SUV ('94 Explorer);
3) the percent unit volume proportions of HSELVs entering the dismantling process by vehicle size class;
4) the estimated mass of HSELVs entering the process; and
5) the assumption that the tires sold for reuse are predominantly regular tires.

The data was sorted and filtered to ensure the aggregated part counts represent the net parts actually recovered and sold from the HSELVs received and processed. Brokered parts and returned parts were excluded. Parts may be returned by customers for a variety of reasons – a part was found to be damaged, a part mechanically failed to work after installation, or the wrong part was sold to the customer, for example.

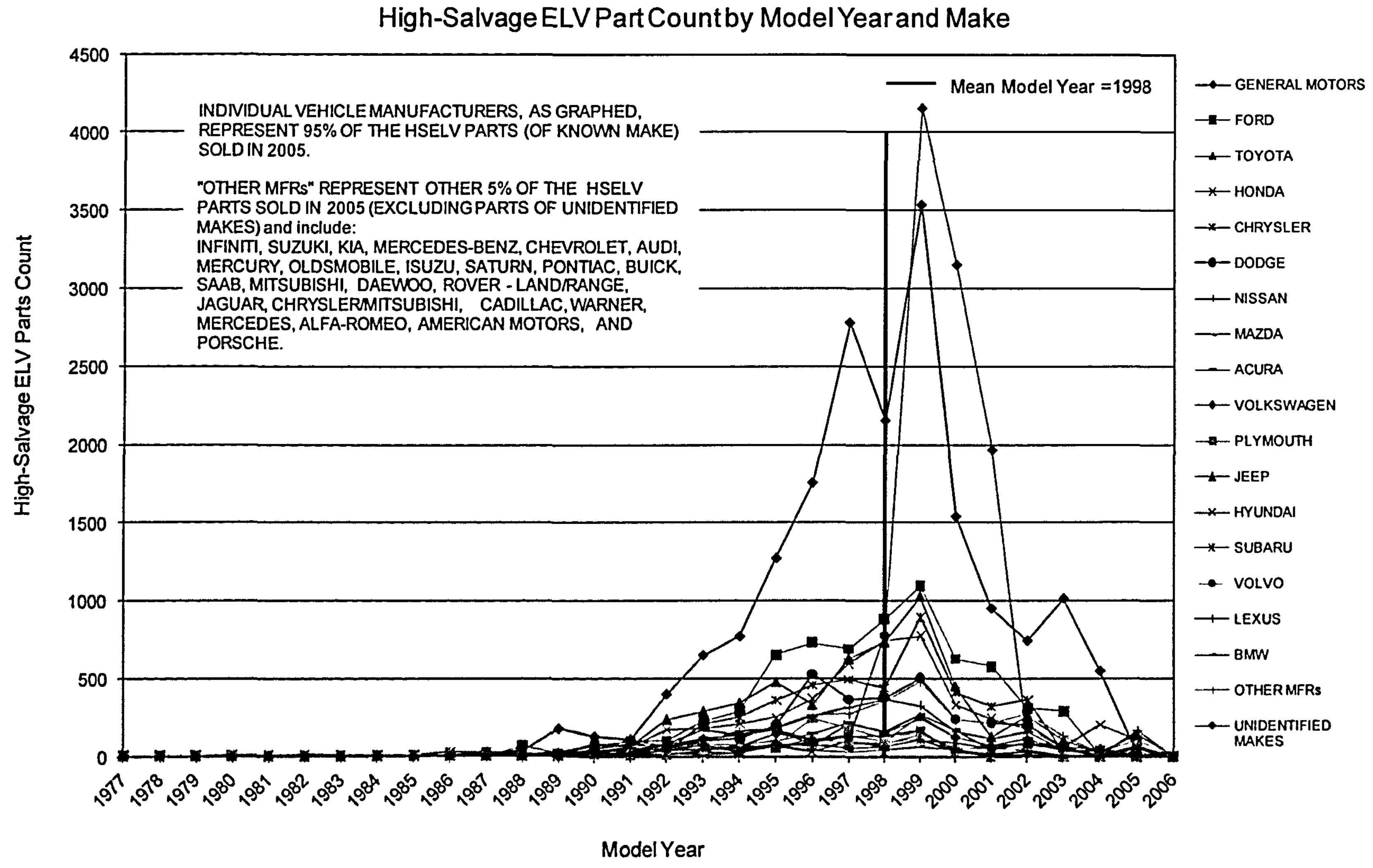


Figure 25 HSELV part counts, for parts sold for direct reuse in 2005, aggregated and plotted by vehicle make and model year.

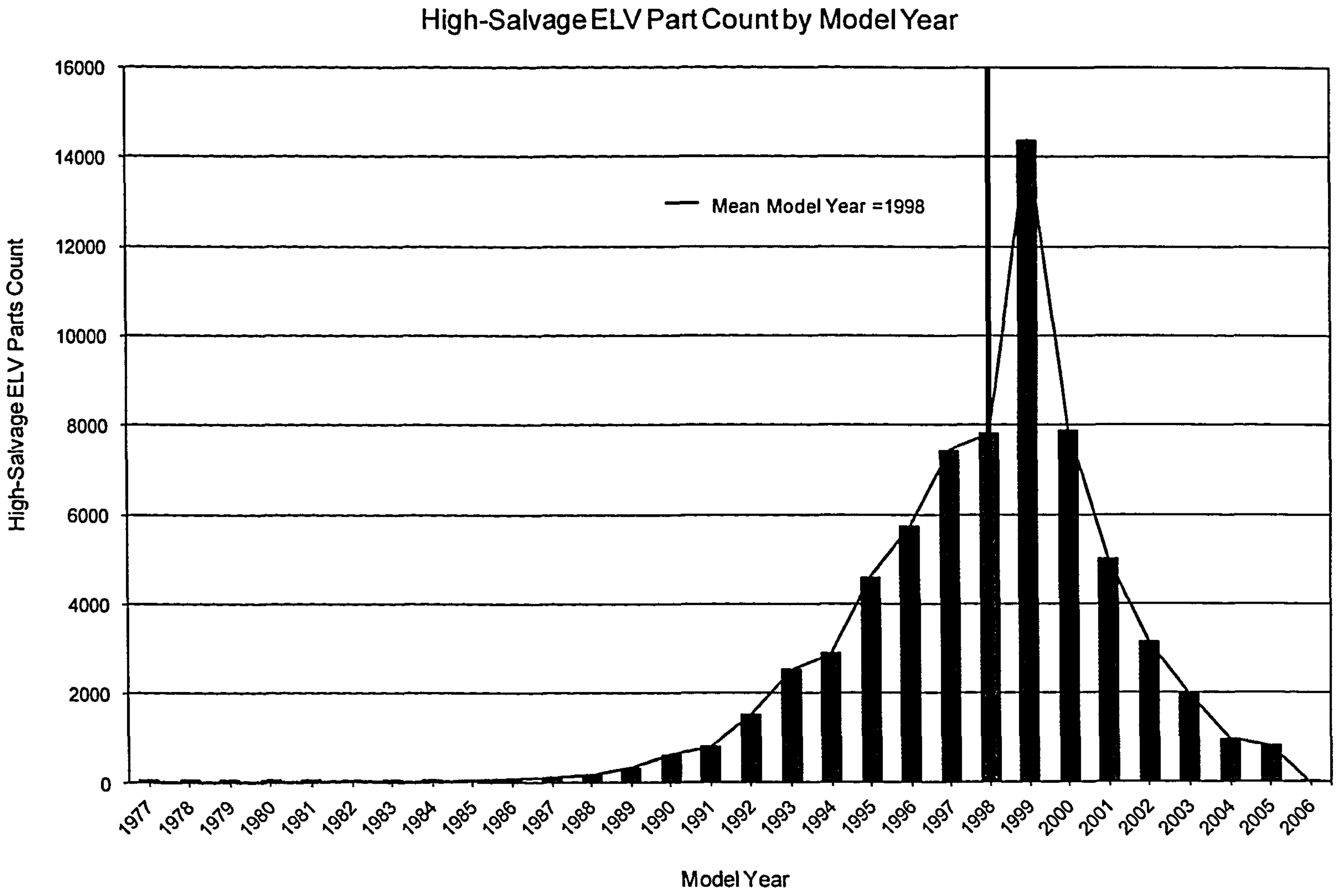


Figure 26 HSELV part counts, for all parts sold for direct reuse in 2005, aggregated and plotted by vehicle model year.

With the exception of a few spare tires from LSELVs sold for reuse, the available part count data for the tires sold for reuse represents predominately regular tires recovered from both LSELVs and HSELVs. On average, LSELVs and HSELVs, respectively, represent 88% and 12% of the ELVs dismantled weekly. To estimate the number of regular tires sold for reuse from HSELVs, the average unit volume proportion of HSELVs processed weekly was applied to the tire part count.

$$Part\ Count\ for\ Regular\ Tires\ from\ HSELVs\ sold\ for\ Reuse, PtCt_{RegTire,HSELVs,Reuse}$$

$$= PtCt_{RegTire,ELVs,Reuse} \times 0.12, \text{where} \qquad [2]$$

$$PtCt_{RegTire,ELVs,Reuse}$$

$$= Part\ Count\ for\ Regular\ Tires\ recovered\ from\ ELVs\ and\ sold\ for\ Reuse$$

Similarly, the part count for batteries sold for reuse represents batteries recovered from both LSELVs and HSELVs. To estimate the number of batteries sold for reuse from HSELVs, the average unit volume proportion of HSELVs processed weekly was applied to the battery part count.

$$Part\ Count\ for\ Batteries\ from\ HSELVs\ sold\ for\ Reuse, PtCt_{Battery,HSELVs,Reuse}$$

$$= PtCt_{Battry,ELVs,Reuse} \times 0.12, \text{where} \qquad [3]$$

$$PtCt_{Battry,ELVs,Reuse} = Part\ Count\ for\ Batteries\ recovered\ from\ ELVs\ and\ sold\ for\ Reuse$$

The HSELV part counts and the vehicle part weights from the Parts Mass Study were applied to the unit volume percentages of vehicles in the different vehicle size classes to estimate the mass of the HSELV parts directed for reuse distributed over the different HSELV size classes. For example, the mass of regular tires recovered from HSELVs and sold for reuse was estimated according to the following equation.

$$Total\ Parts\ Mass\ (kg) of\ Regular\ Tires\ from\ HSELVs\ bound\ for\ Reuse,$$

$$TPM_{RegTire,HSELVs,Reuse} =$$

$$= PtCt_{RegTire,HSELVs,Reuse} \left[PtWt_{RegTire,Neon}\left(\%VVeh_{HSELVs,T} + \%VVeh_{HSELVs,S} + \%VVeh_{HSELVs,C} + \%VVeh_{HSELVs,M}\right) + PtWt_{RegTire,Voyager}\left(\%VVeh_{HSELVs,L} + \%VVeh_{HSELVs,W} + \%VVeh_{HSELVs,V}\right) + PtWt_{RegTire,Explorer}\left(\%VVeh_{HSELVs,SP} + \%VVeh_{HSELVs,P}\right)\right] \div 100, where: \qquad [4]$$

$$PtCt_{RegTire,HSELVs,Reuse} = Part\ Count\ for\ Regular\ Tires\ from\ HSELVs\ bound\ for\ Reuse;$$

$$PtWt_{RegTire,Neon} = Part\ Weight\ (kg) for\ Regular\ Tire\ from\ 1997\ Neon;$$

$$PtWt_{RegTire,Voyager} = Part\ Weight\ (kg) for\ Regular\ Tire\ from\ 1996\ Voyager;$$

$$PtWt_{RegTire,Explorer} = Part\ Weight\ (kg) for\ Regular\ Tire\ from\ 1994\ Explorer;$$

$$\%VVeh_{HSELVs,T} = \%\ Unit\ Volume\ HSELVs\ in\ Two\ seater (T)\ Vehicle\ Size\ Class;$$

$$\%VVeh_{HSELVs,S} = \%\ Unit\ Volume\ HSELVs\ in\ Subcompact (S)\ Vehicle\ Size\ Class;$$

$$\%VVeh_{HSELVs,C} = \%\ Unit\ Volume\ HSELVs\ in\ Compact (C)\ Vehicle\ Size\ Class;$$

$\%VVeh_{HSELVs,L} = \%\ Unit\ Volume\ HSELVs\ in\ Largesize(L)\ Vehicle\ Size\ Class;$

$\%VVeh_{HSELVs,M} = \%\ Unit\ Volume\ HSELVs\ in\ Midsize(M)\ Vehicle\ Size\ Class;$

$\%VVeh_{HSELVs,W} = \%\ Unit\ Volume\ HSELVs\ in\ Station\ Wagon(W)\ Vehicle\ Size\ Class;$

$\%VVeh_{HSELVs,SP} = \%\ Unit\ Volume\ HSELVs\ in\ Special\ Purpose(SP)\ Vehicle\ Size\ Class;$

$\%VVeh_{HSELVs,P} = \%\ Unit\ Volume\ HSELVs\ in\ Pickup(P)\ Vehicle\ Size\ Class.$

This calculation method assumes that 1) HSELV part count varies proportionally with the proportion of HSELVs processed by vehicle size class, and 2) part weight will vary proportionally with vehicle size. This calculation method was preferred to simply applying the arithmetic average of the vehicle part weights from the Parts Mass Study to the part counts. It is anticipated to yield a mass estimate value that is more representative of the overall mass of parts recovered from the ELVs because it is reasonable to expect part counts will vary somewhat with the proportion of vehicles processed by vehicle size class and part weights will vary with vehicle size.

In fact applying the arithmetic averages of the vehicle part weights from the Parts Mass Study to the part counts tended to result in parts mass estimates that were greater than the parts mass estimates based on part counts and the part weights distributed over the different vehicle size classes. For example, the estimated mass of HSELV parts recovered and sold for reuse was 1,184,529 kg based on mean part weights, which is higher than the 1,126,824 kg estimate based on parts weights and part counts distributed by vehicle size class, representing a difference of 1.9% weight of the HSELVs processed. However, to confirm this conjecture, parts counts should be assessed by part type, relative to vehicle count by vehicle size class in future research work (refer to Appendix D, Calculation Methodology, for further information).

Figures 27, 28, 29, and 30 illustrate the estimated weight proportions of the 151 part types recovered from the HSELVs (in kg/tonne HSELVs processed) and sold for reuse. The data is plotted in order of decreasing weight proportion, with up to 40 part types presented on each graph. The first 38 part types plotted in Figure 27 represent 97% by weight of all the parts recovered from the HSELVs and sold for reuse. This data is also summarized in Table 39 in Appendix E.

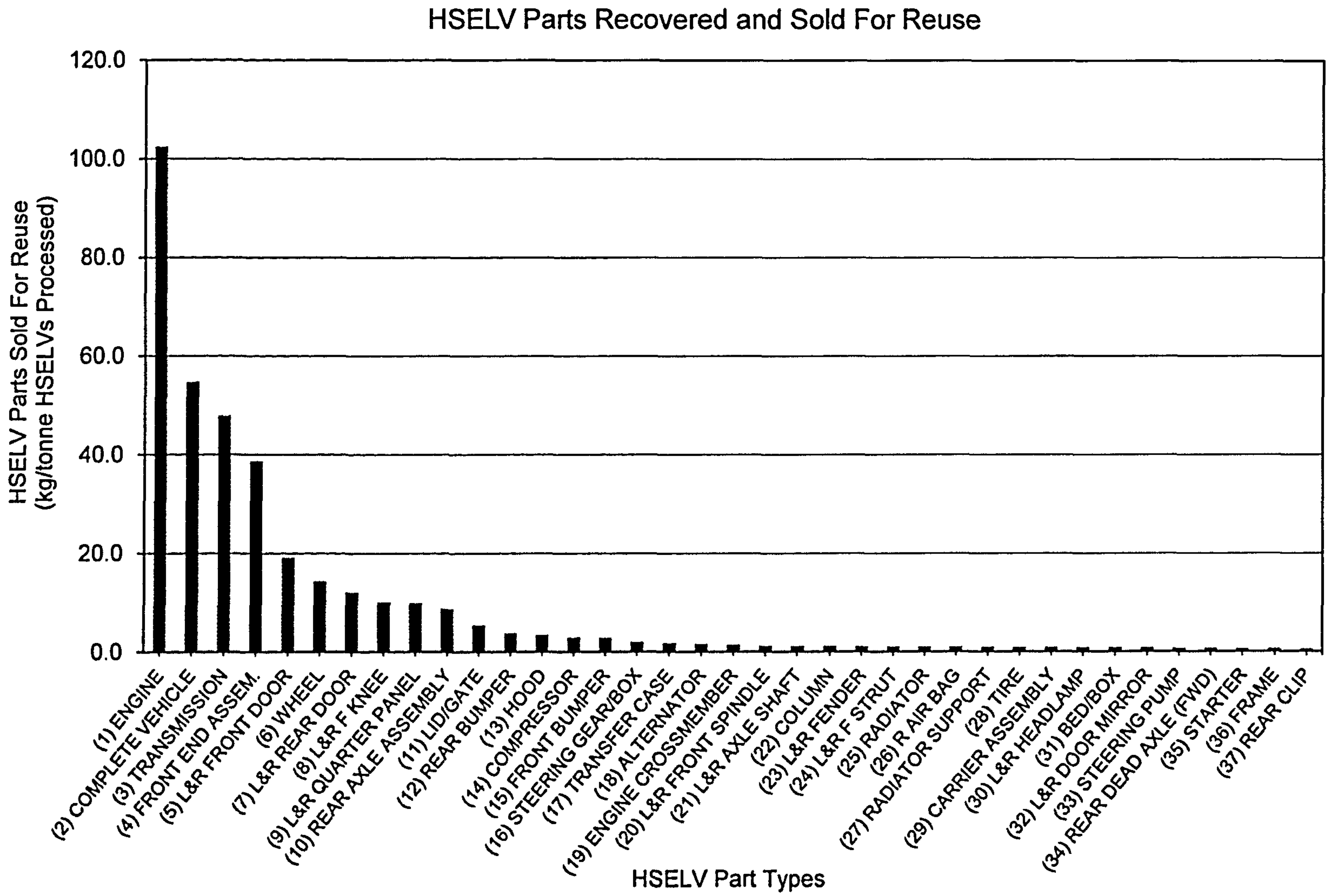


Figure 27 HSELV parts recovered and sold for reuse, with HSELV parts types (1) to (37) presented in order of decreasing weight proportion.

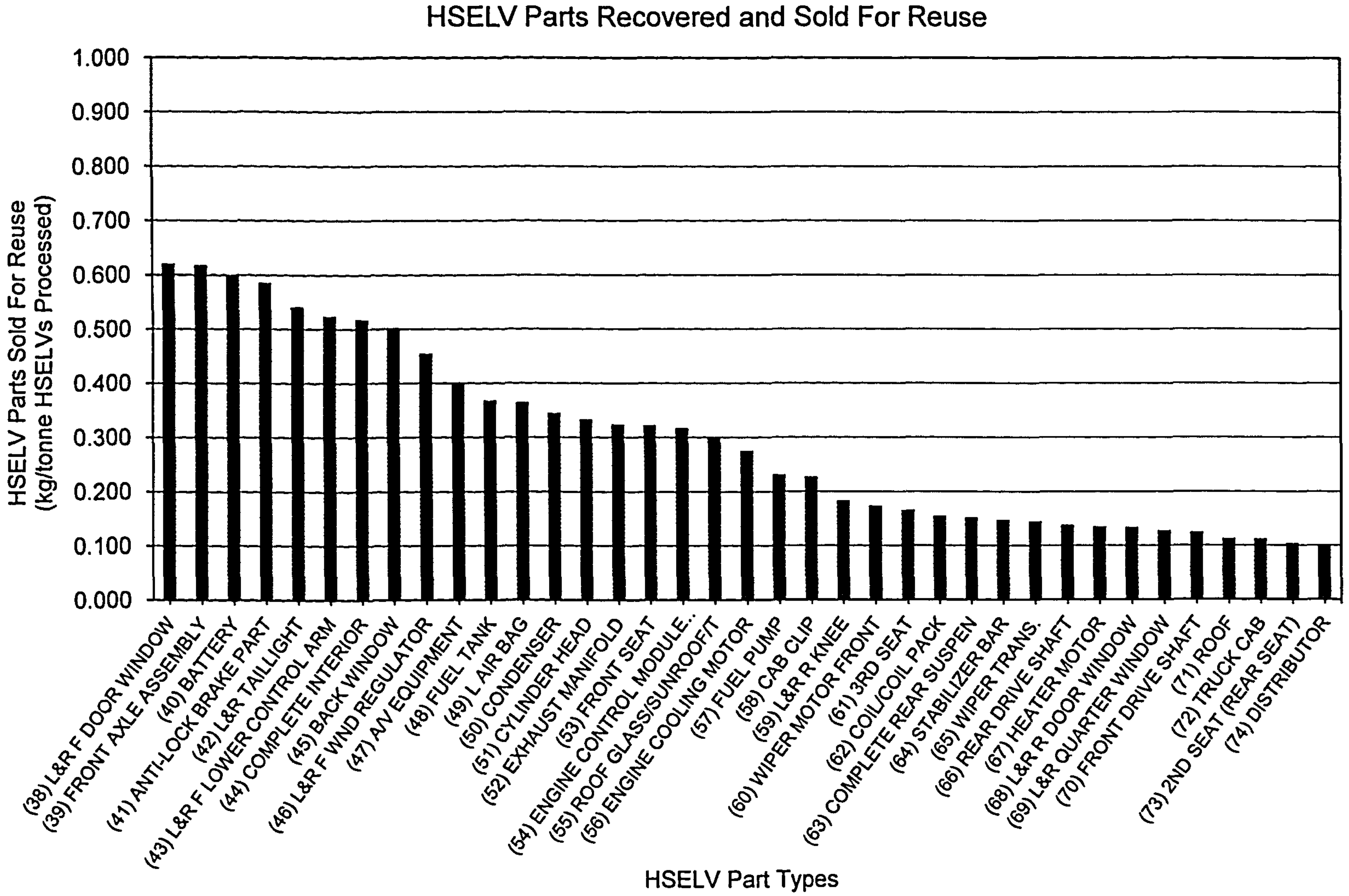


Figure 28 HSELV parts recovered and sold for reuse, with HSELV parts types (38) to (74) presented in order of decreasing weight proportion.

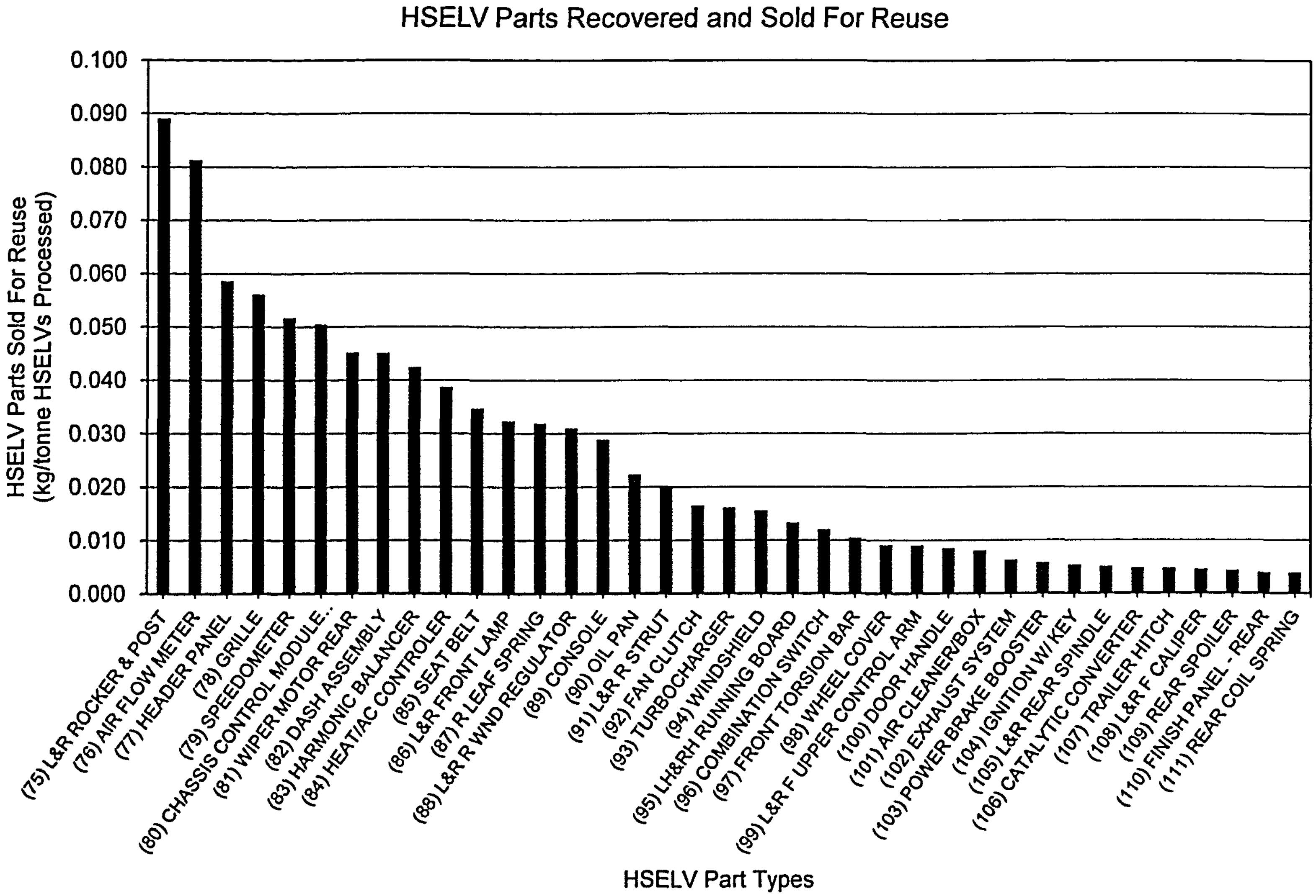


Figure 29 HSELV parts recovered and sold for reuse, with HSELV parts types (75) to (111) presented in order of decreasing weight proportion.

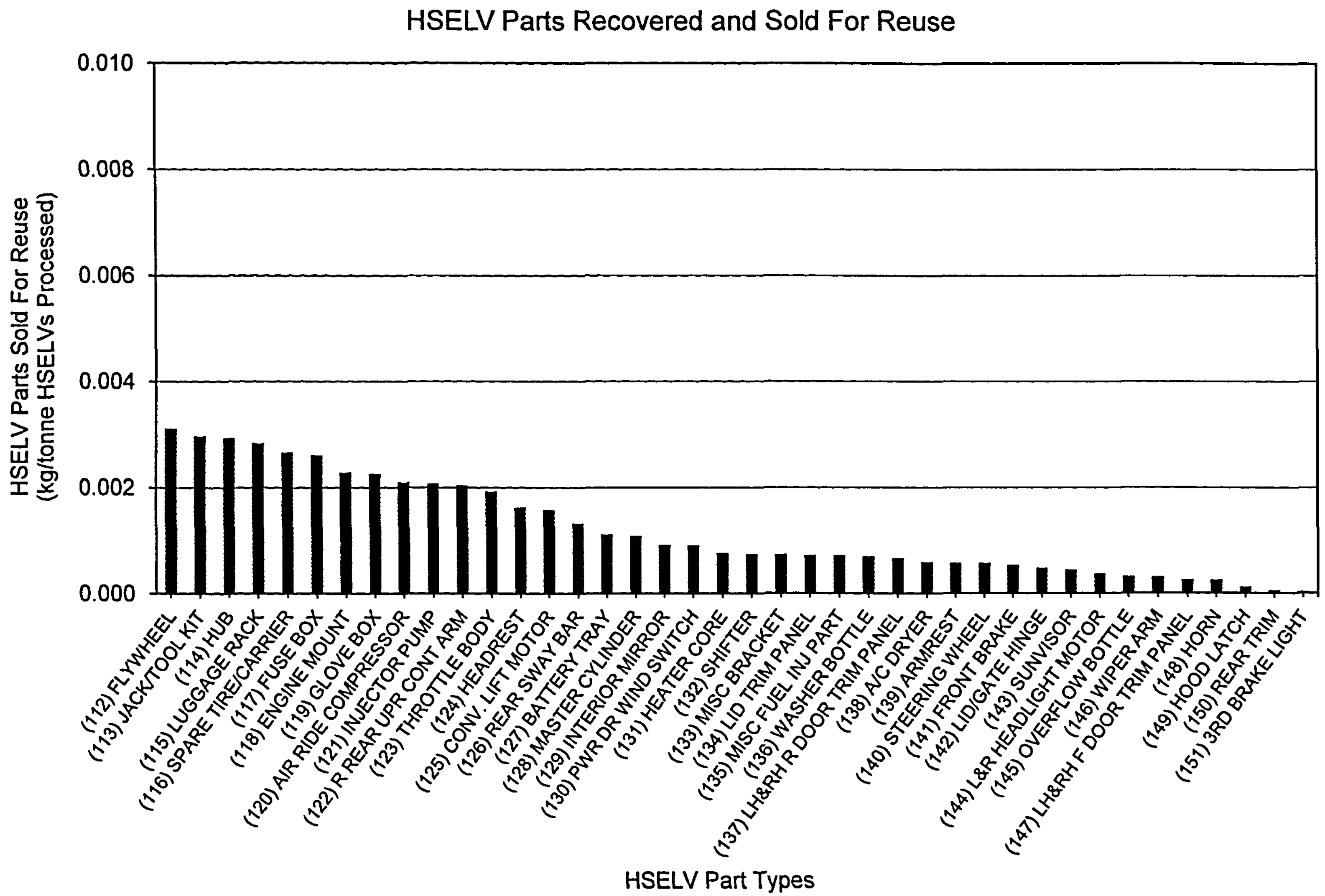


Figure 30 HSELV parts recovered and sold for reuse, with HSELV parts types (112) to (151) presented in order of decreasing weight proportion.

As indicated in Table 21, a little less than 40% of the HSELVs by weight may be recovered and directed for reuse, representing approximately 5% by weight of the ELVs processed annually.

Table 21 Summary of parts recovered from HSELVs for Reuse

	Weight			
	kg per tonne HSELVs Processed	% Wgt. of HSELVs Processed	kg per tonne ELVs Processed	% Wgt. of ELVs Processed
HSELV Parts Sold For Reuse	369.4	36.94%	48.9	4.89%

6.1.2.1.2 Reusable Parts from LSELVs

The reusable LSELV parts information is based on 6 months of "UPIC" parts sales data and includes 655 part types and part counts. The UPIC (or "U-Pull-It") facility is a self-service facility. After removal of fluids, batteries, catalytic convertors, and tires, LSELVs are placed into a yard where customers may come and pull the parts themselves, using their own tools, and buy them at a reduced price. Not all LSELVs received and processed by the dismantler are circulated through the UPIC yard. Only a proportion of the LSELVs received annually are selected and directed through the UPIC facility. The dismantler advised that at any one time approximately 1000 vehicles are maintained in the UPIC yard. Approximately once every six weeks the dismantler "scraps out" a small number of these UPIC vehicles as their strippable parts are depleted. The vehicles that are "scrapped out" are removed from the UPIC yard, crushed and directed for shredding with other ELV hulks. As vehicles are scrapped out from the UPIC yard, they are replaced with "fresh" vehicles. The dismantler does not systematically monitor or track the number of LSELVs that are passed through the UPIC facility annually, or the makes and models of the UPIC vehicles. As a consequence, the proportion of LSELVS received annually and circulated through the UPIC yard it is not known. Also the makes, models and size classes of these vehicles is not known. What is known is that the vehicles that are processed annually through the UPIC facility are accounted for in the total number of LSELVs received and processed annually by the dismantler.

The mass proportions of LSELV parts sold for reuse were calculated using the LSELV part counts and:

1) vehicle part weights from the Parts Mass Study;
2) part weights from a dissembled vehicle database provided by the United States Council for Automotive Research (USCAR) Vehicle Recycling Partnership (VRP); or
3) part weight data found for automotive parts on the World Wide Web.

Principally the vehicle parts weights from the Parts Mass Study were used for the mass flow calculations unless representative part weights were unavailable. In this case, the parts weights were used from the other data sources: the USCAR VRP disassembled vehicle database, or internet based sources (refer to Appendix D, Calculation Methodology for further information).

Part weights could be estimated and assigned to 598 of the 655 part types. Part weights could not be assigned to the other 57 parts types because part weight data was not available or the part types were ambiguous (*e.g.*, "Heat Riser"; "Misc"). Although part weights could not be established for 57 of the 655 part types, the 598 parts types account for 96.8% of the LSELV parts sold for reuse over the 6-month period. The part weights tabulated for each of the 598 part types were averaged by part type and then applied to their respective part count to estimate a mass flow for each LSELV part type. The mass of the LSELV engine assemblies sold for reuse, for example, was estimated using the following equation.

$$Total\ Parts\ Mass\ (kg) of\ Engine\ Assemblies\ from\ LSELVs\ sold\ for\ Reuse\ annually,$$

$$TPM_{Engine,LSELV,Reuse} =$$

$$= PtCt_{Engine,LSELV,Reuse}\left[\frac{(PtWt_{Engine,Neon} + PtWt_{Engine,Voyager} + PtWt_{Engine,Explorer})}{3}\right] \qquad [5]$$

$$\times 2, where:$$

$$PtCt_{Engine,LSELV,Reuse} = 6\text{-}months\ Part\ Count\ for\ Engine\ Assemblies\ from\ LSELVs\ sold\ for\ reuse;$$

$$PtWt_{Engine,Neon} = Part\ Weight\ (kg) for\ Engine\ from\ 1997\ Neon;$$

$$PtWt_{Engine,Voyager} = Part\ Weight\ (kg) for\ Engine\ from\ 1996\ Voyager;$$

$$PtWt_{Engine,Explorer} = Part\ Weight\ (kg) for\ Enginefrom\ 1994\ Explorer$$

Arithmetic average part weights were used to estimate the mass flow of LSELV reusable parts instead of part weights distributed over the LSELV size classes, because the proportion of LSELVs processed through the UPIC yard and their makes, models and size classes are not known.

Table 22 summarizes the LSELV parts recovered for reuse. Approximately 9.3% of the LSELVs by weight may be recovered and directed for reuse, representing 0.8% by weight of the ELVs processed annually. Table 40 in Appendix F summarizes the 598 LSELV part types recovered and sold for reuse and their estimated weight proportions.

Table 22 Summary of parts recovered from LSELVs for reuse

	Weight			
	kg per tonne LSELVs Processed	% Wgt. of LSELVs Processed	kg per tonne ELVs Processed	% Wgt. of ELVs Processed
LSELV Parts Sold For Reuse	9.32	0.93%	8.09	0.81%

6.1.2.1.3 Reusable CORE Parts

Table 23 summarizes the CORE parts types that were sold for reuse in 2005 including quantities. Although CORE parts represent less than 1% of the combined mass of ELVs and CORE parts entering the dismantling process, almost 20% of the CORE parts, by weight, are sold for reuse.

Table 23 Summary of CORE parts directed for reuse

	Weight			
Part Type	kg per tonne CORE Parts Received	% Wgt. of CORE Parts Received	kg per tonne ELVs and CORE Parts Processed	% Wgt. of ELVs and CORE Parts Processed
Transfer Case	1.54	0.15%	0.0015	0.00015%
Transmission	168.37	16.84%	0.1634	0.01634%
Engine	23.88	2.39%	0.0232	0.00232%
Rear Axle Assembly	4.47	0.45%	0.0043	0.00043%
Total	198.27	19.83%	0.192	0.0192%

The mass proportions of CORE parts sold for reuse were calculated using CORE part counts and vehicle part weights from the Parts Mass Study. The vehicle part weights tabulated for each part type were averaged by part type and then applied to their respective part count to estimate mass flow for each CORE part type. The mass of the CORE engine assemblies sold for reuse, for example, was estimated using the following equation.

$$Total\ Parts\ Mass\ (kg) of\ CORE\ Engine\ Assemblies\ sold\ for\ Reuse, TPM_{Engine,CORE,Reuse} =$$

$$PtCt_{Engine,CORE,Reuse}\left[\frac{(PtWt_{Engine,Neon}+PtWt_{Engine,Voyager}+PtWt_{Engine,Explorer})}{3}\right], where: \qquad [6]$$

$PtCt_{Engine,CORE,Reuse} = Part\ Count\ for\ CORE\ Engine\ Assemblies\ \ sold\ for\ reuse;$

$PtWt_{Engine,Neon} = Part\ Weight\ (kg) for\ Engine\ from\ 1997\ Neon;$

$PtWt_{Engine,Voyager} = Part\ Weight\ (kg) for\ Engine\ from\ 1996\ Voyager;$

$PtWt_{Engine,Explorer} = Part\ Weight\ (kg) for\ Enginefrom\ 1994\ Explorer$

6.1.2.2 Parts Recovered For Remanufacturing

Parts sold by dismantlers for remanufacturing, can include CORE parts received by the dismantlers, HSELV parts deleted from inventory, as well as parts recovered from HSELVs deemed unsuitable for reuse, but acceptable for remanufacture. Table 24 summarizes some parts types typically sold for remanufacturing, including quantities.

Table 24 Summary of HSELV parts directed for remanufacturing

	Weight			
Part Type	kg per tonne HSELVs Processed	% Wgt. of HSELVs Processed	kg per tonne ELVs Processed	% Wgt. of ELVs Processed
AC Compressor	0.844	0.084%	0.112	0.011%
Alternator	1.474	0.147%	0.195	0.020%
L&R F Caliper	1.550	0.155%	0.205	0.021%
Steering Gear	1.381	0.138%	0.183	0.0183%
Steering Pump	0.666	0.067%	0.088	0.009%
Starter	2.851	0.285%	0.377	0.038%
Total	8.766	0.877%	1.160	0.116%

It should be noted that the part types that may be sold for remanufacturing will be driven by regional market demands, the availability and locality of parts remanufacturers and the specific parts types the remanufacturers process. For example, one of the participating dismantlers indicated that it never collects engines for remanufacturing, but some other dismantlers do.

To estimate the quantities of parts recovered and sold for remanufacturing, remanufacturable parts count data supplied by the dismantler for one operating year was used, as well as:

1) the part weights for the parts collected from the Parts Mass Study vehicles - the compact sedan ('97 Neon), the minivan ('96 Voyager) and the SUV ('94 Explorer);
2) the percent unit volume proportions of HSELVs entering the dismantling process by vehicle size class; and
3) the estimated mass of HSELVs processed in 2005.

The remanufacturable parts data provided by the dismantler and presented in this analysis does not distinguish between the quantities of parts that are CORE parts from those recovered from HSELVs. The dismantler that contributed the data advised that the majority of the parts directed for remanufacturing come from the HSELVs they process. For this analysis, it is assumed the remanufacturable parts are parts principally recovered from HSELVs.

The remanufacturable part counts and the vehicle part weights from the Parts Mass Study were applied to the unit volume percentages of vehicles in the different vehicle size classes to estimate the mass of the parts directed for remanufacturing distributed over the different HSELV size classes. For example, the mass of A/C compressors recovered from HSELVs and shipped for remanufacturing was estimated according to the following equation.

$$\begin{aligned}
&\mathit{Total\ Parts\ Mass\ (kg) of\ AC\ Compressors\ from\ HSELVs\ bound\ for\ Remanufacturing,}\\
&TPM_{AC\ Compressor,HSELVs,ReMfg} =\\
&PtCt_{Compressor,HSELVs,ReMfg}\left[PtWt_{Compressor,Neon}\left(\%VVeh_{HSELVs,T} + \%VVeh_{HSELVs,S}\right.\right. \qquad [7]\\
&\quad \left.+ \%VVeh_{HSELVs,C} + \%VVeh_{HSELVs,M}\right)\\
&\quad + PtWt_{Compressor,Voyager}\left(\%VVeh_{HSELVs,L} + \%VVeh_{HSELVs,W} + \%VVeh_{HSELVs,V}\right)\\
&\quad \left.+ PtWt_{Compressor,Explorer}\left(\%VVeh_{HSELVs,SP} + \%VVeh_{HSELVs,P}\right)\right] \div 100, \mathit{where:}
\end{aligned}$$

$PtCt_{Compressor,HSELVs,ReMfg}$
$\quad = \mathit{Part\ Count\ for\ AC\ Compressors\ from\ HSELVs\ bound\ for\ Remanufacturing;}$
$PtWt_{Compressor,Neon} = \mathit{Part\ Weight\ (kg) for\ AC\ Compressor\ from\ 1997\ Neon;}$
$PtWt_{Compressor,Voyager} = \mathit{Part\ Weight\ (kg) for\ AC\ Compressor\ from\ 1996\ Voyager;}$
$PtWt_{Compressor,Explorer} = \mathit{Part\ Weight\ (kg) for\ AC\ Compressor\ from\ 1994\ Explorer;}$
$\%VVeh_{HSELVs,T} = \%\ \mathit{Unit\ Volume\ HSELVs\ in\ Two\ seater(T)\ Vehicle\ Size\ Class;}$
$\%VVeh_{HSELVs,S} = \%\ \mathit{Unit\ Volume\ HSELVs\ in\ Subcompact(S)\ Vehicle\ Size\ Class;}$
$\%VVeh_{HSELVs,C} = \%\ \mathit{Unit\ Volume\ HSELVs\ in\ Compact(C)\ Vehicle\ Size\ Class;}$
$\%VVeh_{HSELVs,M} = \%\ \mathit{Unit\ Volume\ HSELVs\ in\ Midsize(M)\ Vehicle\ Size\ Class;}$
$\%VVeh_{HSELVs,L} = \%\ \mathit{Unit\ Volume\ HSELVs\ in\ Largesize(L)\ Vehicle\ Size\ Class;}$
$\%VVeh_{HSELVs,W} = \%\ \mathit{Unit\ Volume\ HSELVs\ in\ Station\ Wagon(W)\ Vehicle\ Size\ Class;}$
$\%VVeh_{HSELVs,SP} = \%\ \mathit{Unit\ Volume\ HSELVs\ in\ Special\ Purpose(SP)\ Vehicle\ Size\ Class;}$
$\%VVeh_{HSELVs,P} = \%\ \mathit{Unit\ Volume\ HSELVs\ in\ Pickup(P)\ Vehicle\ Size\ Class.}$

6.1.2.3 Parts Recovered For Recycling

The parts types recovered from HSELVs and LSELVs and directed for recycling (independently of the ELV hulk and parts destined for shredding), includes tires, batteries, catalytic converters, and mercury switches. Although lead wheel weights are removed voluntarily by some dismantlers, recovery data was not available.

With the exception of batteries recovered and directed for recycling, weight data (for example shipment net weights) was not available from the dismantlers for the tires or the catalytic converters that were recovered from the ELVs and shipped for recycling.

To estimate the quantities of tires and catalytic converters recovered and directed for recycling, part counts were calculated based on the numbers of HSELVs and LSELVs entering the process, the quantities of these parts recovered from HSELVs and LSELVs and sold for reuse, and the following assumptions:

1) each ELV enters the process with 5 tires - 4 regular and 1 spare;
2) the tires sold for reuse are predominantly regular tires; and
3) each ELV entering the process, and having a model year ≥ 1975, has at least one catalytic converter, given 1975 is the first model year that catalytic converters became mandatory on series-production automobiles [Williams, 1993].

With the exception of a few spare tires from LSELVs sold for reuse, the part count for the tires sold for reuse represents tires, predominately regular tires, recovered from both LSELVs and HSELVs. To estimate the number of tires sold from LSELVs and those from HSELVs, the average unit volume proportions of LSELVs and HSELVs processed weekly were applied to the tire part count. On average, LSELVs and HSELVs, respectively, represent 88% and 12% of the ELVs dismantled weekly. Hence, the number of tires from LSELVs sold for reuse, for example, was calculated as follows.

$$Part\ Count\ for\ Regular\ Tires\ from\ LSELVs\ sold\ for\ Reuse, PtCt_{RegTire,LSELVs,Reuse}$$

$$= PtCt_{RegTire,ELVs,Reuse} \times 0.88, \text{where} \qquad [8]$$

$$PtCt_{RegTire,ELVs,Reuse}$$

$$= Part\ Count\ for\ Regular\ Tires\ recovered\ from\ ELVs\ and\ sold\ for\ Reuse$$

The quantity of regular tires recovered from LSELVs and directed for recycling was subsequently calculated, as follows, assuming each ELV enters the process with 4 regular tires.

$$Part\ Count\ for\ Regular\ Tires\ from\ LSELVs\ bound\ for\ Recycling, PtCt_{RegTire,LSELVs,Recycle}$$

$$= (VehCt_{LSELVs,2005} \times 4) - PtCt_{RegTire,LSELVs,Reuse}, \text{where:} \qquad [9]$$

$$VehCt_{LSELVs,2005} = Vehicle\ Count\ for\ LSELVs\ processed\ in\ 2005$$

$$PtCt_{RegTire,LSELVs,Reuse} = Part\ Count\ for\ Regular\ Tires\ from\ LSELVs\ sold\ for\ Reuse$$

The mass proportions of tires and catalytic converters recovered from the LSELVs and HSELVs and directed for recycling, were calculated using the estimated tire and catalytic converter counts and:

1) the part weights of the tires and catalytic converters collected from the Parts Mass Study vehicles - the compact sedan ('97 Neon), the minivan ('96 Voyager) and the SUV ('94 Explorer);
2) the percent unit volume proportions of LSELVs entering the dismantling process by vehicle size class; and
3) the percent unit volume proportions of HSELVs entering the dismantling process by vehicle size class.

The part count estimates and vehicle part weights from the Parts Mass Study were applied to the unit volume percentages of vehicles in the different vehicle size classes to estimate the mass of the tires and catalytic converters directed for recycling distributed over the different LSELV and HSELV size classes. For example, the mass of regular tires recovered from LSELVs and shipped for recycling was estimated according to the following formula.

$$\begin{aligned}
&\mathit{Total\ Parts\ Mass\ (kg) of\ Regular\ Tires\ from\ LSELVs\ bound\ for\ Recycling,}\\
&TPM_{RegTire,LSELVs,Recycle} =\\
&= PtCt_{RegTire,LSELVs,Reccyle}\Bigg[PtWt_{RegTire,Neon}(\%VVeh_{LSELVs,T} + \%VVeh_{LSELVs,S}\\
&\quad + \%VVeh_{LSELVs,C} + \%VVeh_{LSELVs,M})\\
&\quad + PtWt_{RegTire,Voyager}(\%VVeh_{LSELVs,L} + \%VVeh_{LSELVs,W} + \%VVeh_{LSELVs,V})\\
&\quad + PtWt_{RegTire,Explorer}(\%VVeh_{LSELVs,SP} + \%VVeh_{LSELVs,P})\\
&\quad + \%VVeh_{LSELVs,U}\frac{(PtWt_{RegTire,Neon} + PtWt_{RegTire,Voyager} + PtWt_{RegTire,Explorer})}{3}\Bigg]\\
&\quad \div 100, \mathit{where}:
\end{aligned} \qquad [10]$$

$PtCt_{RegTire,LSELVs,Reccyle} = \mathit{Part\ Count\ for\ Regular\ Tires\ from\ LSELVs\ bound\ for\ Recycling};$

$PtWt_{RegTire,Neon} = \mathit{Part\ Weight\ (kg) for\ Regular\ Tire\ from}\ 1997\ \mathit{Neon};$

$PtWt_{RegTire,Voyager} = \mathit{Part\ Weight\ (kg) for\ Regular\ Tire\ from}\ 1996\ \mathit{Voyager};$

$PtWt_{RegTire,Explorer} = \mathit{Part\ Weight\ (kg) for\ Regular\ Tire\ from}\ 1994\ \mathit{Explorer};$

$\%VVeh_{LSELVs,T} = \%\ \mathit{Unit\ Volume\ LSELVs\ in\ Two\ seater (T)\ Vehicle\ Size\ Class};$

$\%VVeh_{LSELVs,S} = \%\ \mathit{Unit\ Volume\ LSELVs\ in\ Subcompact (S)\ Vehicle\ Size\ Class};$

$\%VVeh_{LSELVs,C} = \%\ \mathit{Unit\ Volume\ LSELVs\ in\ Compact (C)\ Vehicle\ Size\ Class};$

$\%VVeh_{LSELVs,M} = \%\ Unit\ Volume\ LSELVs\ in\ Midsize(M)\ Vehicle\ Size\ Class;$

$\%VVeh_{LSELVs,L} = \%\ Unit\ Volume\ LSELVs\ in\ Largesize(L)\ Vehicle\ Size\ Class;$

$\%VVeh_{LSELVs,W} = \%\ Unit\ Volume\ LSELVs\ in\ Station\ Wagon(W)\ Vehicle\ Size\ Class;$

$\%VVeh_{LSELVs,SP} = \%\ Unit\ Volume\ LSELVs\ in\ Special\ Purpose(SP)\ Vehicle\ Size\ Class;$

$\%VVeh_{LSELVs,P} = \%\ Unit\ Volume\ LSELVs\ in\ Pickup(P)\ Vehicle\ Size\ Class;$

$\%VVeh_{LSELVs,U} = \%\ Unit\ Volume\ LSELVs\ in\ Unknown(U)\ Vehicle\ Size\ Class$

Weight data was provided by one dismantler for the batteries it recovered and shipped for recycling. However, a preliminary estimate of the maximum quantity of batteries recovered and directed for recycling was calculated assuming each ELV enters the process with a battery. Hence battery part counts were calculated based on the numbers of HSELVs and LSELVs entering the process, the quantities of these parts recovered from HSELVs and LSELVs and sold for reuse, and assuming a battery is onboard and recovered from each ELV processed.

As the case for the tires sold for reuse, the part count for the batteries sold for reuse represents batteries recovered from both LSELVs and HSELVs. Hence, to estimate the number of batteries sold for reuse from LSELVs and those from HSELVs, the average unit volume proportions of LSELVs and HSELVs processed weekly (88% and 12%, respectively) were applied to the battery part count. The number of batteries from LSELVs sold for reuse, for example, was calculated as follows.

$$Part\ Count\ for\ Batteries\ from\ LSELVs\ sold\ for\ Reuse, PtCt_{Battery,LSELVs,Reuse}$$
$$= PtCt_{Battery,ELVs,Reuse} \times 0.88, \text{where} \qquad [11]$$

$PtCt_{Battery,ELVs,Reuse} = Part\ Count\ for\ Batteries\ recovered\ from\ ELVs\ and\ sold\ for\ Reuse$

The maximum quantity of batteries that could be recovered from the LSELVs and directed for recycling was subsequently calculated, as follows, assuming each ELV enters the process with one battery.

$$Maximum\ Part\ Count\ for\ Batteries\ from\ LSELVs\ bound\ for\ Recycling,$$
$$PtCt_{Max,Battery,LSELVs,Reccyle} =$$
$$= (VehCt_{LSELVs,2005} \times 1 battery/ELV) - PtCt_{Battery,LSELVs,Reuse}, \text{where:} \qquad [12]$$

$VehCt_{LSELVs,2005} = Vehicle\ Count\ for\ LSELVs\ processed\ in\ 2005$

$PtCt_{Battery,LSELVs,Reuse} = Part\ Count\ for\ Batteries\ from\ LSELVs\ sold\ for\ Reuse$

The maximum mass proportions of batteries recovered from the LSELVs and HSELVs and directed for recycling, were calculated using the estimated battery counts and:

1) the part weights of the batteries collected from the Parts Mass Study vehicles - the compact sedan ('97 Neon), the minivan ('96 Voyager) and the SUV ('94 Explorer);
2) the percent unit volume proportions of LSELVs entering the dismantling process by vehicle size class; and
3) the percent unit volume proportions of HSELVs entering the dismantling process by vehicle size class.

The battery part count estimates and the vehicle part weights from the Parts Mass Study were applied to the unit volume percentages of vehicles in the different vehicle size classes to estimate the mass of the batteries directed for recycling distributed over the different LSELV and HSELV size classes. For example, the maximum mass of batteries recovered from LSELVs and shipped for recycling was estimated according to the following formula.

$$\begin{aligned}
&Maximum\ Total\ Parts\ Mass\ (kg) of\ Batteries\ from\ LSELVs\ bound\ for\ Recycling,\\
&TPM_{Max,Battery,LSELVs,Recycle} =\\
&PtCt_{Max,Battery,LSELVs,Reccyle}\Bigg[PtWt_{Battery,Neon}(\%VVeh_{LSELVs,T} + \%VVeh_{LSELVs,S}\\
&\quad + \%VVeh_{LSELVs,C} + \%VVeh_{LSELVs,M})\\
&\quad + PtWt_{Battery,Voyager}(\%VVeh_{LSELVs,L} + \%VVeh_{LSELVs,W} + \%VVeh_{LSELVs,V})\\
&\quad + PtWt_{Battery,Explorer}(\%VVeh_{LSELVs,SP} + \%VVeh_{LSELVs,P})\\
&\quad + \%VVeh_{LSELVs,U}\frac{(PtWt_{Battery,Neon} + PtWt_{Battery,Voyager} + PtWt_{Battery,Explorer})}{3}\Bigg]\\
&\quad \div 100, where:
\end{aligned} \qquad [13]$$

$PtCt_{Max,Battery,LSELVs,Reccyle} = Maximum\ Part\ Count\ for\ Batteries\ from\ LSELVs\ bound\ for\ Recycling;$

$PtWt_{Battery,Neon} = Part\ Weight\ (kg) for\ Batteries\ from\ 1997\ Neon;$

$PtWt_{Battery,Voyager} = Part\ Weight\ (kg) for\ Batteries\ from\ 1996\ Voyager;$

$PtWt_{Battery,Explorer} = Part\ Weight\ (kg) for\ Batteries\ from\ 1994\ Explorer;$

$\%VVeh_{LSELVs,T} = \%\ Unit\ Volume\ LSELVs\ in\ Two\ seater (T)\ Vehicle\ Size\ Class;$

$\%VVeh_{LSELVs,S} = \%\ Unit\ Volume\ LSELVs\ in\ Subcompact (S)\ Vehicle\ Size\ Class;$

$\%VVeh_{LSELVs,C} = \%\ Unit\ Volume\ LSELVs\ in\ Compact (C)\ Vehicle\ Size\ Class;$

$\%VVeh_{LSELVs,M} = \%\ Unit\ Volume\ LSELVs\ in\ Midsize (M)\ Vehicle\ Size\ Class;$

$\%VVeh_{LSELVs,L} = \%\ Unit\ Volume\ LSELVs\ in\ Largesize (L)\ Vehicle\ Size\ Class;$

$\%VVeh_{LSELVs,W} = \%\ Unit\ Volume\ LSELVs\ in\ Station\ Wagon (W)\ Vehicle\ Size\ Class;$

$\%VVeh_{LSELVs,SP} = \%\ Unit\ Volume\ LSELVs\ in\ Special\ Purpose(SP)\ Vehicle\ Size\ Class;$

$\%VVeh_{LSELVs,P} = \%\ Unit\ Volume\ LSELVs\ in\ Pickup(P)\ Vehicle\ Size\ Class;$

$\%VVeh_{LSELVs,U} = \%\ Unit\ Volume\ LSELVs\ in\ Unknown(U)\ Vehicle\ Size\ Class$

The resulting estimated maximum mass of batteries recovered and directed for recycling is 11.0 kg and 10.1 kg, respectively, per tonne of LSELVs and HSELVs processed.

The actual mass of the batteries typically recovered and shipped for recycling is much less, as indicated by the shipment weight data provided by the dismantler for the batteries it shipped for recycling. The mass of batteries actually shipped for recycling represents only about 81% by weight of the estimated "maximum" mass of batteries shipped. When batteries sold for reuse and those shipped for recycling are both accounted for, it is estimated only 82% of the ELVs enter the dismantling process with a battery on board. The dismantler that provided the battery shipment weight data indicated that it was not unusual to receive an ELV without a battery on board; for example a former vehicle owner may remove the battery before relinquishing the vehicle.

To estimate the weight of batteries sold for reuse from LSELVs and those from HSELVs, the average unit volume proportions of LSELVs and HSELVs processed weekly (88% and 12%, respectively) were applied to the weight of batteries shipped. For example, the weight of batteries recovered from LSELVs and shipped for recycling was calculated as follows.

$Total\ Parts\ Mass\ (kg) of\ Batteries\ from\ LSELVs\ shipped\ for\ Recycling,$

$TPM_{Batteries,LSELVs,Recycle} =$

$$= TPM_{Batteries,ELVs,Recycle} \times 0.88, \text{where} \qquad [14]$$

$TPM_{Batteries,ELVs,Reuse} = Total\ Parts\ Mass\ (kg) of\ Batteries\ recovered\ from\ ELVs\ and\ shipped\ for\ Recycling$

The quantity of mercury switches recovered and directed for recycling was calculated using the unit part count of mercury switches recovered from the LSELVs and HSELVs processed in one year, the average weight of two mercury switches collected from the SUV ('94 Explorer) during the Parts Mass Study, and the estimated mass of LSELVs and HSELVs entering the dismantling process. Refer to Appendix D, Calculation Methodology, for further information.

Table 25 summarizes the estimated weight proportions (in kg/tonne) of tires, batteries, catalytic converters, and mercury switches recovered from the LSELVs and

Table 25 Summary of parts recovered from LSELVs and HSELVs for Recycling

	Parts Recovered for Recycling					
	From LSELVs		From HSELVs		From LSELVs and HSELVs	
Part type	kg per tonne LSELVs processed	kg per tonne total ELVs processed	kg per tonne HSELVs processed	kg per tonne total ELVs processed	kg per tonne total ELVs processed	% Wgt of total ELVs processed
Tires, Regular	23.5	20.4	21.9	2.9	23.3	2.33%
Tires, Spare	3.0	2.6	2.8	0.4	2.9	0.29%
Batteries	8.9	7.7	8.1	1.1	8.8	0.88%
Catalytic Convertors	4.1	3.6	3.9	0.5	4.1	0.41%
Mercury Switches					0.009	0.001%

HSELVs and directed for recycling. The quantities of batteries directed for recycling are based on the actual battery shipment weight data. On the other hand, the estimates for the quantities of tires and catalytic converters directed for recycling represent upper limits considering it is unlikely each ELV entering the process will have 5 tires, and each ELV of model year 1975 or newer will have at least one catalytic converter.

6.1.2.4 Fluids Recovered From Processed ELVS

The fluid types recovered from HSELVs and LSELVs that can be accounted for include engine oil, transmission oil, power steering fluid, antifreeze, windshield washer fluid, and gasoline. These represent the fluid types that are recovered by the majority of the participating dismantlers. Although refrigerants were recovered by the dismantlers, the quantity of refrigerants collected was not available.

To estimate the quantities of fluids recovered and directed for reuse and/or recycling, fluid quantities were calculated based on the numbers of HSELVs and LSELVs entering the process and the quantities of these types of fluids collected from the Parts Mass Study vehicles - the compact sedan ('97 Neon), the minivan ('96 Voyager) and the SUV ('94 Explorer). For example, the quantity of antifreeze recovered from the LSELVs and HSELVs and shipped for recycling was estimated according to the following formula.

$$Total\ Fluid\ Weight\ for\ Antifreeze\ recovered\ from\ ELVs, TFWt_{Antifreeze,ELVs} =$$

$$= VehCt_{ELVs}\left[\frac{(RFWt_{Antifreeze,Neon} + RFWt_{Antifreeze,Voyager} + RFWt_{Antifreeze,Explorer})}{3}\right], \qquad [15]$$

where:

$VehCt_{ELVs} = Vehicle\ Count\ for\ total\ ELVs\ processed;$

$RFWt_{Antifreeze,Neon} = Recovered\ Fluid\ Weight\ (kg) for\ Antifreeze\ from\ 1997\ Neon;$

$RFWt_{Antifreeze,Voyager} = Recovered\ Fluid\ Weight\ (kg) for\ Antifreeze\ from\ 1996\ Voyager;$

$RFWt_{Antifreeze,Explorer} = Recovered\ Fluid\ Weight\ (kg) for\ Antifreeze\ from\ 1994\ Explorer$

Table 26 summarizes the estimated weight proportions (in kg/tonne) of engine oil, transmission oil, power steering fluid, antifreeze, windshield washer fluid, and gasoline recovered from the LSELVs and HSELVs and directed for reuse and/or recycling. The used lubricants are bulked up and either recycled offsite by licensed liquid waste recyclers, or used on-site for energy recovery, *i.e.*, comfort heating in used oil-fired space heaters. The antifreeze, windshield washer fluid, and gasoline are reused on-site, or sold to customers for off-site reuse.

Table 26 Summary of fluids recovered from LSELVs and HSELVs

		Disposition of Recovered Fluids	
Fluid		Recycling (kg/tonne ELVs processed)	Reuse (kg/tonne ELVs processed)
Lubricants	Engine Oil	2.1	0.0
	Transmission Oil	3.1	0.0
	Differential Fluid	0.0	0.0
	Brake-line Fluids	0.0	0.0
	Power Steering Fluid	0.1	0.0
Antifreeze		0.0	4.1
Windshield Washer Fluid		0.0	0.9
Gasoline		0.0	8.8
Totals =		5.3	13.8

The participant dismantlers either did not have written records of the fluids recovered from the ELVs processed at their facilities, or if they did, the information was not contributed for the LCI.

6.1.2.5 HSELV Parts Deleted from Inventory

The dismantlers routinely clean-up their parts inventories. HSELV parts will be purged from inventory because they are old, overstocked, or damaged. Some of these parts may be directed for remanufacturing, but predominantly these "scrapped out" parts are directed for shredding with ELV hulks. To estimate the quantity of HSELV parts typically deleted from inventory, deleted parts data by vehicle make, model and model year, supplied by one of the participating dismantlers for one operating year was used as well as:

1) the part weights for the parts collected from the Parts Mass Study vehicles - the compact sedan ('97 Neon), the minivan ('96 Voyager) and the SUV ('94 Explorer);
2) the percent unit volume proportions of HSELVs entering the dismantling process by vehicle size class; and
3) the estimated mass of HSELVs processed in 2005.

The HSELV deleted part count data was sorted, and aggregated, by vehicle make, model, and model year and is graphically presented in Figures 31 and 32, with HSELV deleted part counts plotted by vehicle make and model year, and for all makes and models combined, respectively.

The HSELV parts deleted from inventory in 2005 consisted of 102 different part types and came from vehicles representing 38 different vehicle manufacturers and 278 different vehicle models, ranging from 1984 to 2006, in model years. The mean model year was calculated for the HSELV deleted parts and for all vehicle makes combined. The mean model year for the HSELV deleted parts is 1997 (versus 1998 for HSELVs parts sold for reuse in 2005), representing an average age of 8 years for the HSELVs parts deleted in 2005 (versus 7 years for HSELVs parts sold for reuse).

The deleted part counts and the vehicle part weights from the Parts Mass Study were applied to the unit volume percentages of vehicles in the different vehicle size classes to estimate the mass of the HSELV parts deleted from inventory distributed over the different HSELV size classes. For example, the mass of HSELVs engines deleted from inventory was estimated according to the following equation.

$Total\ Parts\ Mass\ (kg)\ of\ Engines\ from\ HSELVs\ Deleted\ from\ inventory,$

$$TPM_{Engine,HSELVs,Delete} = $$

$$= PtCt_{Engine,HSELVs,Delete}\left[PtWt_{Engine,Neon}\left(\%VVeh_{HSELVs,T} + \%VVeh_{HSELVs,S} + \%VVeh_{HSELVs,C} + \%VVeh_{HSELVs,M}\right) + PtWt_{Engine,Voyager}\left(\%VVeh_{HSELVs,L} + \%VVeh_{HSELVs,W} + \%VVeh_{HSELVs,V}\right) + PtWt_{Engine,Explorer}\left(\%VVeh_{HSELVs,SP} + \%VVeh_{HSELVs,P}\right)\right] \div 100, where: \quad [16]$$

$PtCt_{Engine,HSELVs,Delete} = Part\ Count\ for\ Engines\ from\ HSELVs\ Deleted\ from\ inventory;$

$PtWt_{Engine,Neon} = Part\ Weight\ (kg) for\ Engine\ from\ 1997\ Neon;$

$PtWt_{Engine,Voyager} = Part\ Weight\ (kg) for\ Engine\ from\ 1996\ Voyager;$

$PtWt_{Engine,Explorer} = Part\ Weight\ (kg) for\ Engine\ from\ 1994\ Explorer;$

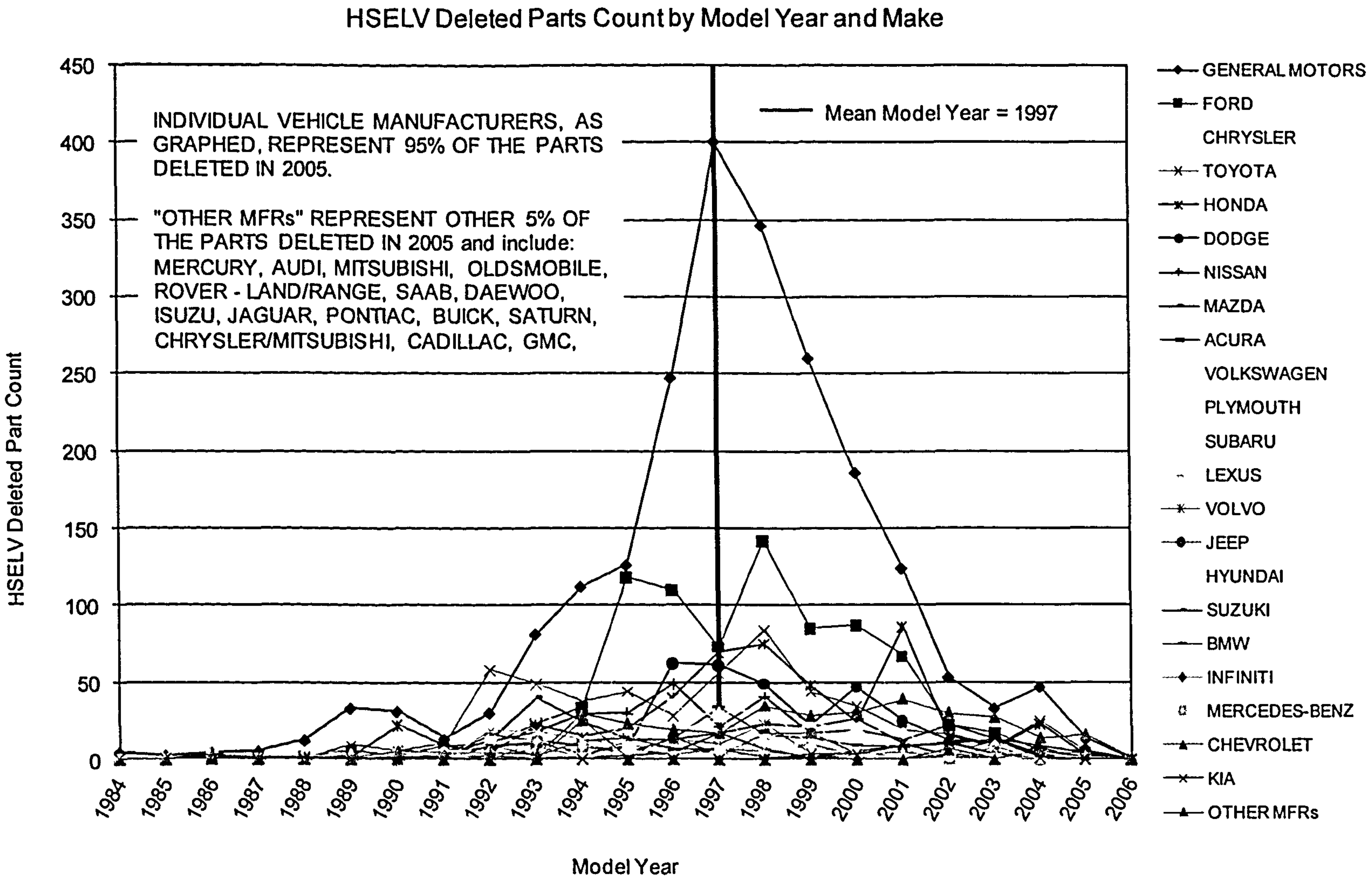


Figure 31 HSELV deleted part counts aggregated and plotted by vehicle make and model year.

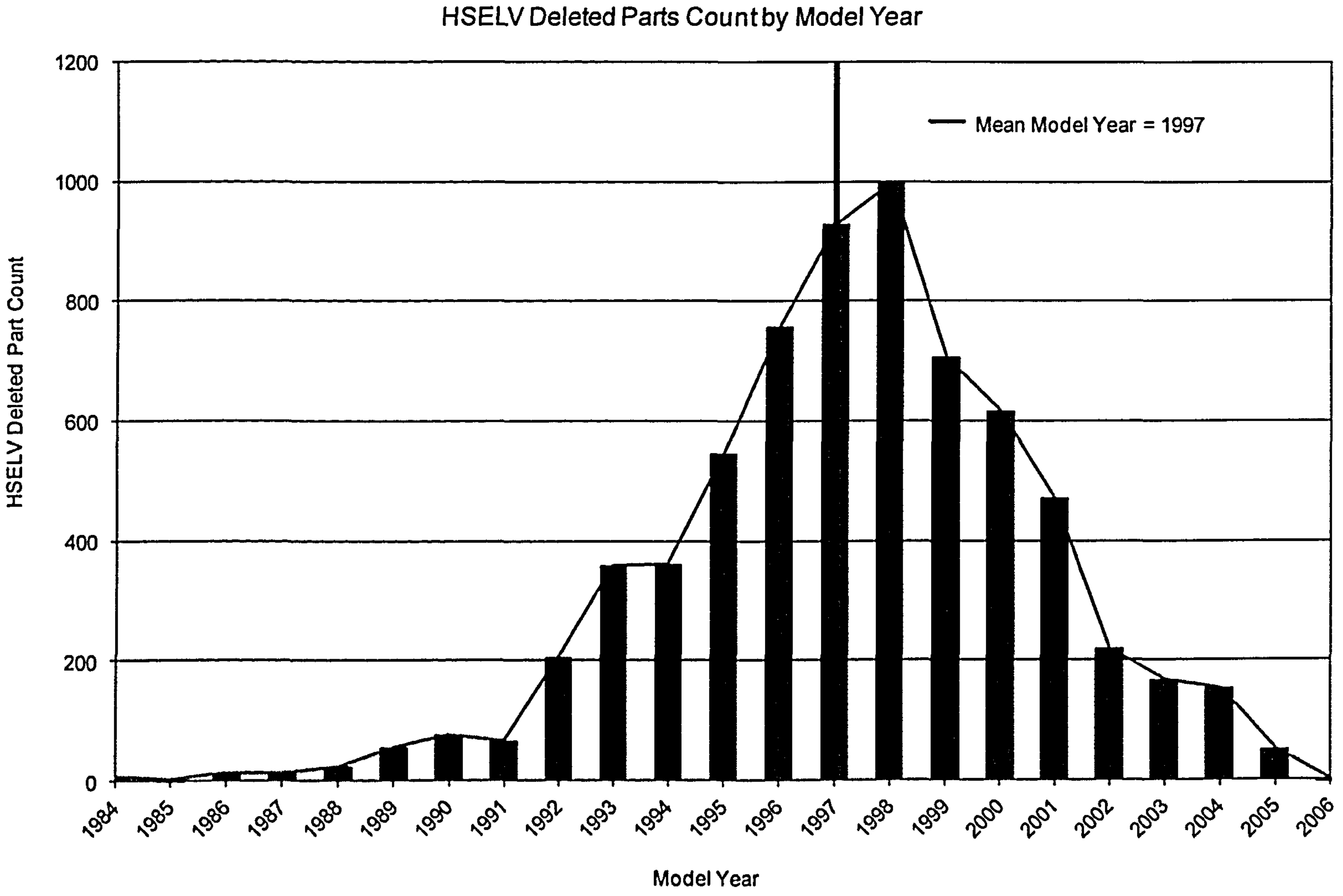


Figure 32 HSELV deleted part counts aggregated and plotted by vehicle model year.

$\%VVeh_{HSELVs,T} = \%\ Unit\ Volume\ HSELVs\ in\ Two\ seater(T)\ Vehicle\ Size\ Class;$

$\%VVeh_{HSELVs,S} = \%\ Unit\ Volume\ HSELVs\ in\ Subcompact(S)\ Vehicle\ Size\ Class;$

$\%VVeh_{HSELVs,C} = \%\ Unit\ Volume\ HSELVs\ in\ Compact(C)\ Vehicle\ Size\ Class;$

$\%VVeh_{HSELVs,M} = \%\ Unit\ Volume\ HSELVs\ in\ Midsize(M)\ Vehicle\ Size\ Class;$

$\%VVeh_{HSELVs,L} = \%\ Unit\ Volume\ HSELVs\ in\ Largesize(L)\ Vehicle\ Size\ Class;$

$\%VVeh_{HSELVs,W} = \%\ Unit\ Volume\ HSELVs\ in\ Station\ Wagon(W)\ Vehicle\ Size\ Class;$

$\%VVeh_{HSELVs,SP} = \%\ Unit\ Volume\ HSELVs\ in\ Special\ Purpose(SP)\ Vehicle\ Size\ Class;$

$\%VVeh_{HSELVs,P} = \%\ Unit\ Volume\ HSELVs\ in\ Pickup(P)\ Vehicle\ Size\ Class.$

Table 27 summarizes the estimated weight proportions of the HSELV parts deleted from inventory in 2005. Deleted parts represent approximately 3% by weight of the HSELVs processed, but only 0.4% by weight of all the ELVs processed.

Table 27 Summary of HSELVs parts deleted from inventory

	Weight			
	kg per tonne HSELVs Processed	% Wgt. of HSELVs Processed	kg per tonne ELVs Processed	% Wgt. of ELVs Processed
HSELV Deleted Parts	29.78	2.98%	3.94	0.39%

What is not understood is if there might be incentives, opportunities or justification to consider redirecting these parts for post-dismantling/pre-shredder recycling instead of shredding them with ELV hulks. These parts may represent potential "missed opportunities" for enhanced materials recovery and recycling. This opportunity should be evaluated as part of follow-up research. Even though the percentage is small, this percentage can be significant on a mass-flow basis. For example the percentage shown in Table 27 represents approximately 90 tonnes annually for this scenario.

6.1.2.6 ELV Hulks and Parts Shipped for Shredding

Once the stripping of parts from the HSELVs and LSELVs is completed the leftover ELV hulks, along with scrapped-out parts, are typically crushed and flattened in preparation for shipping them to the shredders,

The quantity of leftover ELV hulks and parts generated by the dismantling process may be estimated as follows.

$Total\ Mass\ (kg) of\ ELV\ Hulks, Deleted\ Parts\ and\ CORE\ Parts\ Shipped\ for\ Shredding,$

$$\begin{aligned} &TM_{ELV\ Hulks\&Parts,Shredding} = \\ &(TVM_{HSELVs,Received} + TVM_{LSELVs,Received} + TPM_{CORE\ Pts,Received}) \\ &\quad - (TPM_{HSELV\ Pts,Reuse} + TPM_{LSELV\ Pts,Reuse} + TPM_{CORE\ Pt,Reuse} + TPM_{HSELV\ Pt,ReMfg} \\ &\quad + TPM_{HSELV\ Pts,Recycle} + TPM_{LSELV\ Pts,Recycle} + TFWt_{ELVs}) + TPM_{HSELV\ Pts,Delete}, where: \end{aligned} \qquad [17]$$

$TVM_{HSELVs,Received} = Total\ Vehicle\ Mass\ (kg) of\ HSELVs\ Received\ and\ processed$

$TVM_{LSELVs,Received} = Total\ Vehicle\ Mass\ (kg) of\ LSELVs\ Received\ and\ processed$

$TPM_{CORE\ Pts,Received} = Total\ Parts\ Mass\ (kg) of\ CORE\ Parts\ Received\ and\ processed$

$TPM_{HSELV\ Pts,Reuse} = Total\ Parts\ Mass\ (kg) of\ HSELV\ Parts\ sold\ for\ Reuse$

$TPM_{LSELV\ Pts,Reuse} = Total\ Parts\ Mass\ (kg) of\ LSELV\ Parts\ sold\ for\ Reuse$

$TPM_{CORE\ Pt,Reuse} = Total\ Parts\ Mass\ (kg) of\ CORE\ Parts\ sold\ for\ Reuse$

$TPM_{HSELV\ Pt,ReMfg} = Total\ Parts\ Mass\ (kg) of\ HSELV\ Parts\ sold\ for\ Remanufacture$

$TPM_{HSELV\ Pts,Recycle} = Total\ Parts\ Mass\ (kg) of\ HSELV\ Parts\ sold\ for\ Recycling$
$(i.e. pre\text{-} shredder\ recycling; parts\ recycled\ independently\ of$
$hulks\ \&\ material\ shipped\ for\ shredding)$

$TPM_{LSELV\ Pts,Recycle} = Total\ Parts\ Mass\ (kg) of\ LSELV\ Parts\ sold\ for\ Recycling$
$(i.e. pre\text{-} shredder\ recycling)$

$TFWt_{ELVs} = Total\ Weight\ of\ Fluids\ recovered\ from\ ELVs,$

$TPM_{HSELV\ Pts,Delete} = Total\ Parts\ Mass\ (kg)\ of\ HSELVs\ Parts\ Deleted\ from\ inventory$

There is a "lag time" from the time a vehicle is first brought into the facility, dismantled and crushed to the time it is actually shipped out as part of a scrap load and received by the shredding facility. This lag time will depend on:

1) the space available at the dismantler for the storage of ELVs received and awaiting dismantling;
2) the time and number of ELVs that can be dismantled daily;
3) the space available for the storage of the stripped ELVs hulks awaiting crushing and/or shipment for shredding; and
4) the time and distance to ship the hulks to a shredding facility.

Based on the data used for this LCI, this lag time is estimated to be approximately 4 months, as illustrated in Figure 33.

Table 28 summarizes the estimated and actual quantities of ELV hulks, deleted parts and CORE parts shipped for shredding. The actual quantity of ELV hulks and deleted parts shipped for shredding is based on scrap load shipment weight data corresponding to the one year operating period of May 2005 to April 2006.

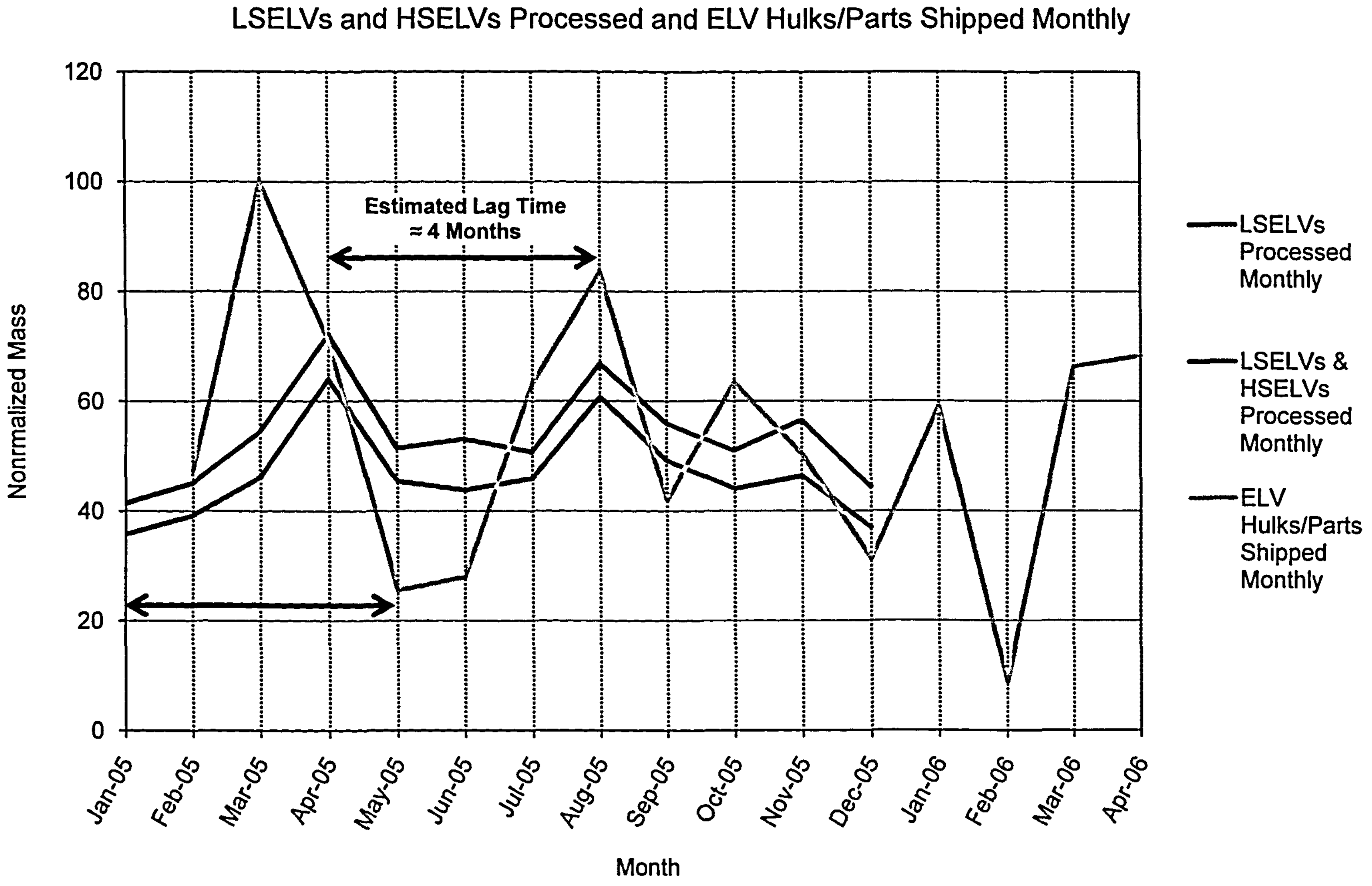


Figure 33 Comparison of the mass (normalized) of LSELVs and HSELVs dismantled monthly and ELV hulks and parts shipped monthly for shredding.

Table 28 Summary of ELV hulks, parts and materials leftover from the dismantling process and shipped for shredding

	Estimated Weight		Actual Weight	
	kg per tonne ELVs and CORE parts Processed	% Wgt. of ELVs and CORE parts Processed	kg per tonne ELVs and CORE parts Processed	% Wgt. of ELVs and CORE parts Processed
ELV Hulks, Parts and Materials	883.7	88.4%	945.5	94.5%

Based on the estimated mass of HSELVs and LSELVs entering the dismantling process, the estimated quantity of ELV hulks, deleted parts and CORE parts shipped for shredding is 883.7 kg per tonne of ELVs and CORE parts received and processed. The estimated value is less than the actual quantity of ELV hulks and parts shipped, representing a difference that is 6.5% of the actual shipped weight value. This error is suspected to be due to a combination of (1) an under estimation of the mass of the ELVs entering the dismantling process and (2) an over estimation of the mass of parts and fluids recovered and directed for reuse, remanufacturing and recycling.

6.1.2.7 Green House Gas (GHG) Emissions Due To Electrical Power Generation

Estimated GHG emissions from electrical power generation sources (CO_2, SO_2, NOx as NO_2) were calculated based on 2005 operating data from Ontario electrical power generating stations [OPG, 2006]. Table 29 summarizes the 2005 GHG emissions from Ontario Power Generation (OPG) sources, by source and for all sources combined. The net electrical energy generation, expressed in GW-hr, represents the total electricity produced by a generating station, *i.e.,* gross generation, minus internal energy use [OPG, 2006].

The GHG emission rates for all generation sources combined and the electrical energy input of 23.1 kW-hr/tonne of ELVs processed were subsequently used to calculate the CO_2, SO_2, and NO_x (as NO_2) emission outputs per tonne ELVs processed (see Appendix D, Calculation Methodology).

Table 29 GHG emissions from Ontario electrical power generating stations in 2005 [OPG, 2006]

	Generation by Source		Tonnes		
	Source	Net GW-hr	CO_2	SO_2	NOx (as NO_2)
GHG Atmospheric Emissions	Fossil	30,938.0	30,198,130.0	113,642.0	39,043.0
	Hydroelectric	31,912.0	0.0	0.0	0.0
	Nuclear	45,005.0	11,459.0	2.2	64.0
	Evergreen	687.0	0.0	0.0	0.0
	Total	108,542.0	30,209,589.0	113,644.2	39,107.0
GHG Emission Rate for all Sources Combined	Tonnes/net GW-hr		278.32	1.05	0.36

Table 30 summarizes the resulting outputs of CO_2, SO_2, and NO_x (as NO_2) per tonne ELVs processed, excluding and including line losses. The resulting emissions of 6.4 kg, 24.2 g, and 8.3 g, respectively, of CO_2, SO_2, and NO_x (as NO_2), per tonne ELVs processed are biased on the low side because they are based on the net electrical energy output at the generation source (OPG) and do not account for emissions resulting from of the electrical energy output required to compensate for the electrical energy losses associated with transmission and distribution through the power grid. Transmission and distribution losses increase with the electrical energy load on the system [USDOE, 2002; USDOE, 2003] and with distance from the source.

Table 30 GHG emissions attributed to electrical energy consumption in the dismantling process

	CO_2	SO_2	NO_X (as NO_2)
	kg/tonne ELVs processed	g/tonne ELVs processed	g/tonne ELVs processed
Excluding emissions due to transmission and distribution losses	6.4	24.2	8.3
Including emissions due to 7% transmission and distribution losses	6.9	25.9	8.9

These trends are demonstrated in Figures 34 and 35, showing total net electricity generation and transmission and distribution losses in the U.S. from 1980 to 2007 [USDOE EIA, 2008], and in Figures 36 and 37, showing net electricity generation and line losses in Canada from 1980 to 2004 [WDID, 2008a; WDID, 2008b]. In both the U.S. and Canada, electricity transmission and distribution losses have tended to increase with increasing electricity generation.

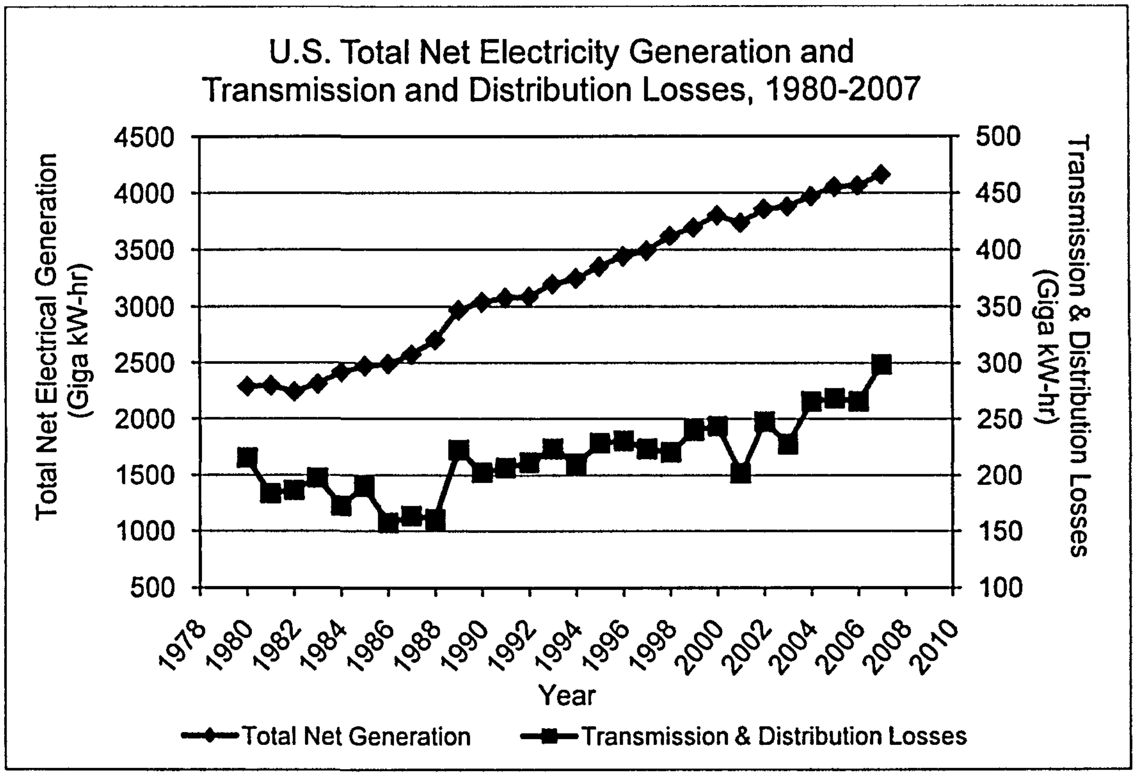


Figure 34 Net electricity generation (Giga kW-hr), and transmission and distribution losses (Giga kW-hr) in the U.S., 1980-2007 [USDOE EIA, 2008].

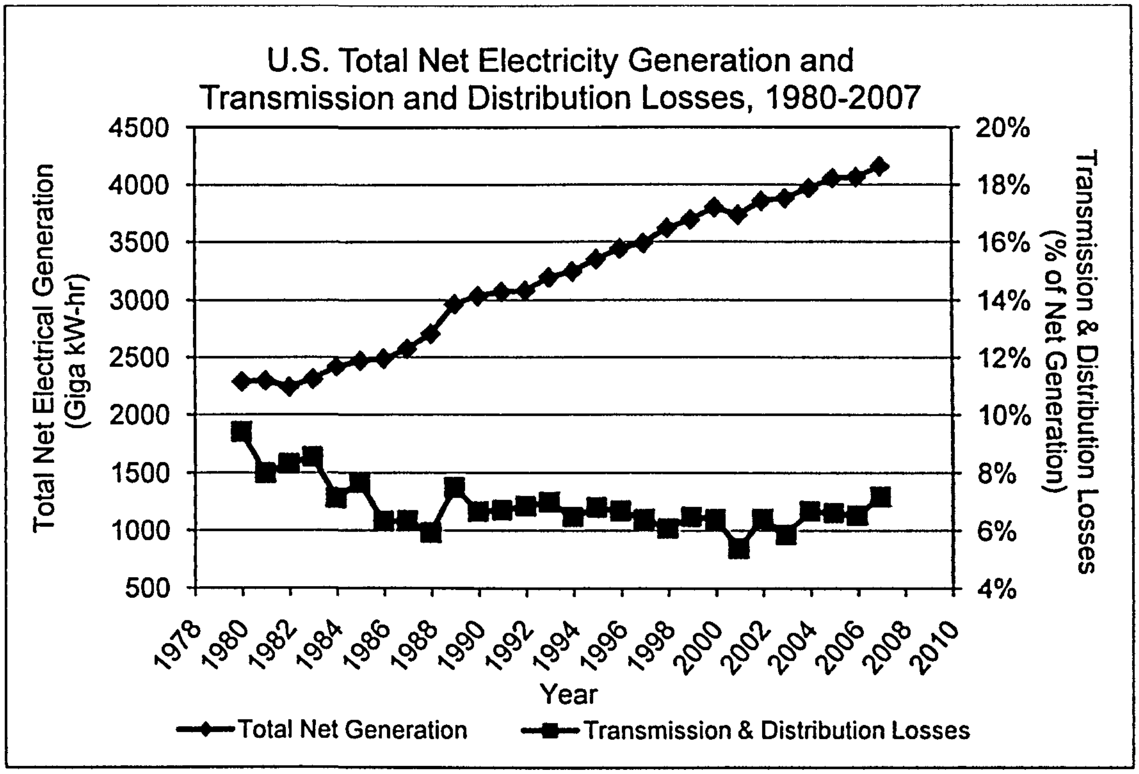


Figure 35 Net electricity generation (Giga kW-hr), and transmission and distribution losses (% of Net Generation) in the U.S., 1980-2007 [USDOE EIA, 2008].

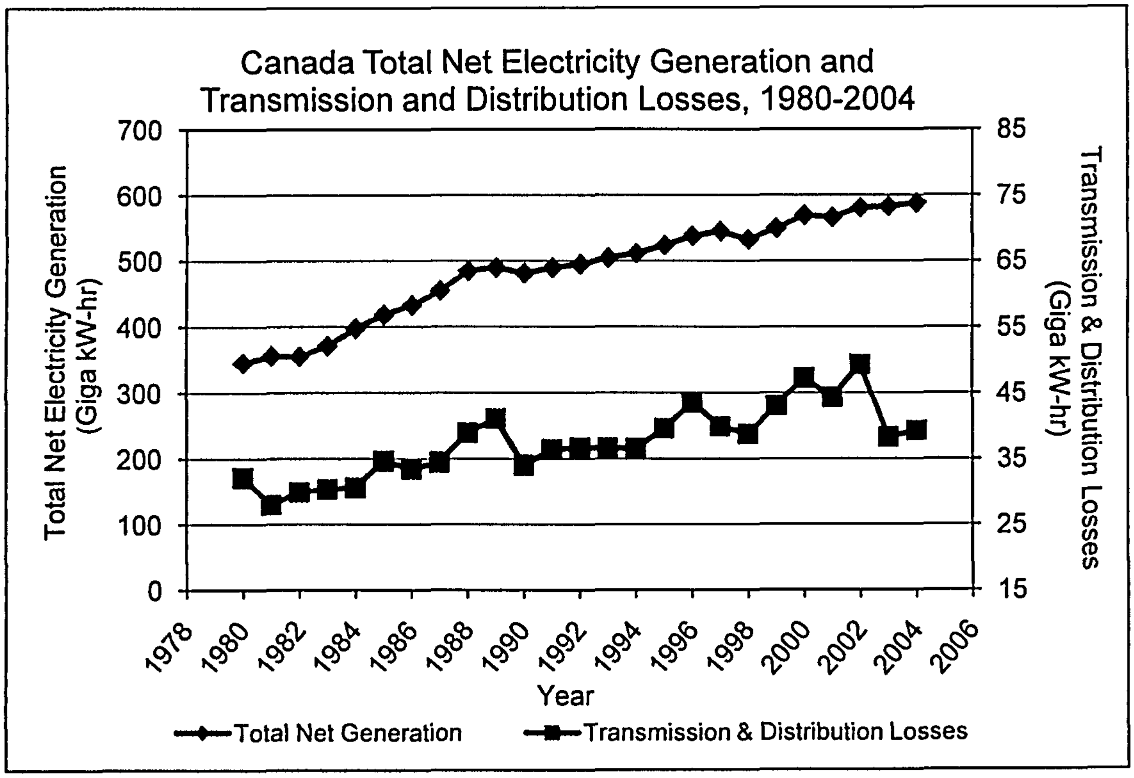


Figure 36 Net electricity generation (Giga kW-hr), and transmission and distribution losses (Giga kW-hr) in Canada, 1980-2004.

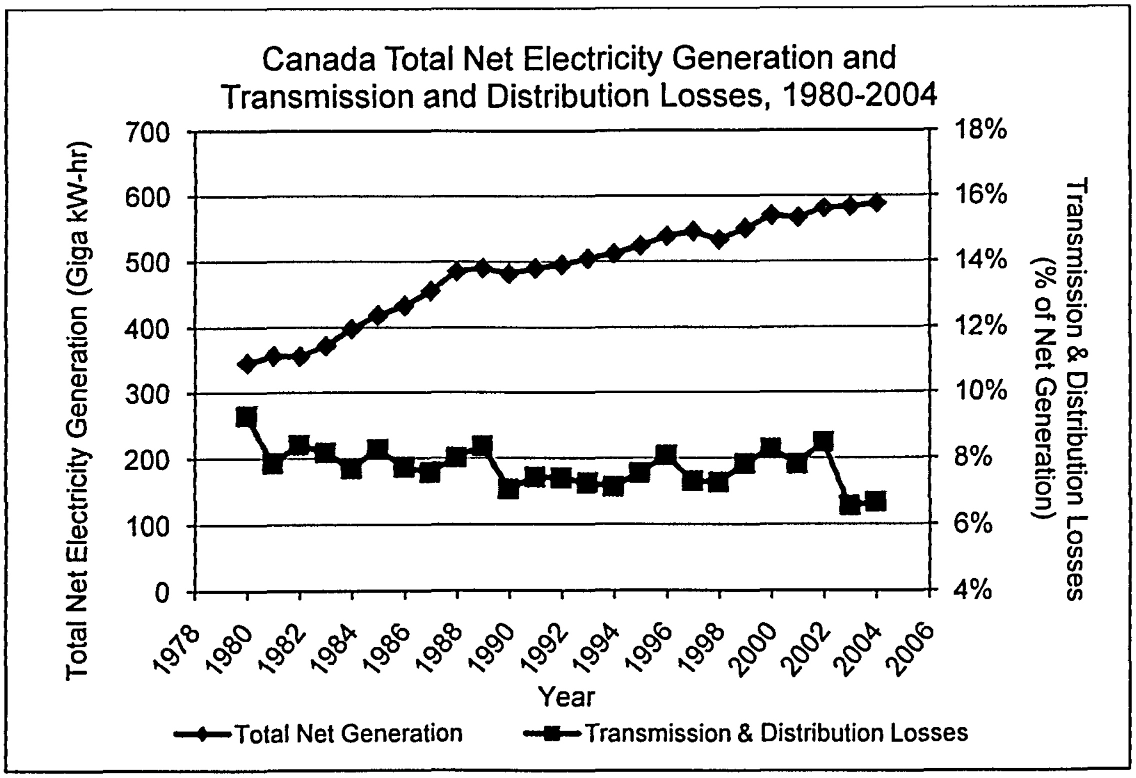


Figure 37 Net electricity generation (Giga kW-hr), and transmission and distribution losses (% of Net Generation) in Canada, 1980-2007.

From 2000 to 2007, line losses in the U.S. averaged about 6.5% of the total net electricity generation (refer to Figure 35), and in Canada, from 1997 to 2004, averaged 7.5% of net generation (refer to Figure 37).

The GHG emissions produced as a result of the electrical energy generated and lost via electricity transmission and distribution have been accounted for in the calculation of the GHG emissions resulting from electrical energy use during dismantling since these emissions occur as a consequence of the demand for electrical energy by the dismantling process. As summarized in Table 30, using an average value of 7% for transmission and distribution losses, an estimated 6.9 kg, 25.9 g, and 8.9 g, respectively, of CO_2, SO_2, and NO_x (as NO_2), are generated as a consequence of electricity use in the dismantling process per tonne ELVs processed (see Appendix D, Calculation Methodology).

6.2 Shredding Process LCI

Table 31 summarizes the energy, water and materials usage and the materials and environmental releases identified for the shredding process. The usage and release criteria are expressed based on the functional units of per tonne of shredder feed material.

6.2.1 Shredding Process Inputs

The inputs to the system - ELV hulks and parts, other oversized metals-rich scrap, electrical energy and process water - are calculated based on actual operating and production data contributed by the participating shredder (see Appendix D, Calculation Methodology). ELV hulks and parts and other oversized metals-rich scrap represent 57.6% and 42.4% of the total mill infeed, respectively. The other oversized metals-rich scrap can consist of demolition and/or construction scrap and large-appliance scrap, ("white goods") that are pre-processed by scrap suppliers for removal of materials that are hazardous and/or environmentally unacceptable for shredding, such as refrigerants and PCB-containing materials.

6.2.2 Shredding Process Outputs

The system outputs include shredded ferrous product (containing approximately 92% recovered ferrous metals and 8% non-ferrous metal and non-metal "contaminants"), non-ferrous residue (containing approximately 80% non-ferrous metals, 2% ferrous metals and 18% non-metallics), shredder residue, process waste water, green house gas (GHG) emissions due to electrical power generation and particulate

Table 31 Summary of LCI systems inputs and outputs for the shredding process

System Inputs and Outputs				Criteria (per tonne of shredder feed material)	Per tonne of Shredder Infeed	% Weight of Shredder Infeed
Inputs	ELV Hulks			kg	576.0	57.6%
	Other Oversized Metals-rich Scrap			kg	424.0	42.4%
	Electrical Energy			kW-hr	28.8	---
	Process Water			liters	5.7	---
Outputs	Shredded Ferrous Product	Total output		kg	775.3	77.5%
		Recovered Metals	Ferrous Metals	kg	713.3	71.3%
		Contaminants and/or Losses	Non-Ferrous Metals & Non-metals	kg	62.0	6.2%
	Non-Ferrous Residue	Total output		kg	32.6	3.3%
		Recovered Metals	Non-Ferrous Metals	kg	26.1	2.6%
		Contaminants and/or Losses	Ferrous Metals	kg	0.7	0.1%
			Non-metals	kg	5.9	0.6%
	Shredder Residue			kg	192.1	19.2%
	Process Waste Water			liters	0	---
	Air Emissions	From Electrical Power Generation (including 7% transmission & distribution losses)	CO_2	kg	8.6	---
			SO_2	g	32.3	---
			NO_X (as NO_2)	g	11.1	---
		From Shredder Air Emission Control Systems	PM	g	15.7	---

matter (PM) air emissions from shredder air emission control systems. The shredded ferrous product, non-ferrous residue, shredder residue, and process waste water outputs are calculated based on actual operating and production data contributed by the participating shredder (see Appendix D, Calculation Methodology). Raw data is not included in the thesis due to data confidentiality and non-disclosure agreements.

Estimated GHG emissions from electrical power generation sources (CO_2, SO_2, NOx as NO_2) were calculated based on 2005 operating data from Ontario electrical power generating stations [OPG, 2006]. Table 32 summarizes the 2005 GHG emissions from Ontario Power Generation (OPG) sources, by source and for all sources combined. The net electrical energy generation, expressed in GW-hr, represents the total electricity produced by a generating station, *i.e.*, gross generation, minus internal energy use [OPG, 2006].

Table 32 GHG emissions from Ontario electrical power generating stations in 2005 [OPG, 2006]

	Generation by Source		Tonnes		
	Source	Net GW-hr	CO_2	SO_2	NOx (as NO_2)
GHG Atmospheric Emissions	Fossil	30,938.0	30,198,130.0	113,642.0	39,043.0
	Hydroelectric	31,912.0	0.0	0.0	0.0
	Nuclear	45,005.0	11,459.0	2.2	64.0
	Evergreen	687.0	0.0	0.0	0.0
	Total	108,542.0	30,209,589.0	113,644.2	39,107.0
GHG Emission Rate for all Sources Combined	Tonnes/net GW-hr		278.32	1.05	0.36

Using the GHG emission rates (tonnes per net GW-hr) for all generation sources combined, the electrical energy input of 28.8 kW-hr/tonne of shredder infeed and an average value of 7% electricity transmission and distribution losses, the CO_2, SO_2, and NOx (as NO_2) emission outputs per tonne shredder infeed were subsequently calculated, excluding and including line losses, and are summarized in Table 33 (see Appendix D, Calculation Methodology).

Table 33 GHG emissions attributed to electrical energy consumption in the shredding process

	CO_2	SO_2	NO_X (as NO_2)
	kg/tonne shredder feed	g/tonne shredder feed	g/tonne shredder feed
Excluding emissions due to transmission and distribution losses	8.0	30.2	10.4
Including emissions due to 7% transmission and distribution losses	8.6	32.3	11.1

Using a value of 7% for transmission and distribution losses, an estimated 8.6 kg, 32.3 g, and 11.1 g, respectively, of CO_2, SO_2, and NO_x (as NO_2), are generated, per tonne of shedder feed, as a consequence of the use of electrical energy in the shredding process.

The PM emissions from shredder air emission control systems were calculated based on a combination of production, operating and source testing data from the contributing shredder and surrogate source testing data published in the Institute of Scrap Recycling Industries, Inc. (ISRI) "Clean Air Act Title V Applicability Workbook"

[ISRI, 1998]. The PM emissions are a summation of PM emissions from the shredder fume control system plus PM emissions from the downstream material/air separation system, expressed per tonne of shredder feed material (see Appendix D, Calculation Methodology).

PM emissions from the shredder fume control equipment (a.k.a. mill "defumer") were calculated based on an estimated PM emission rate of 0.14 g/sec. This emission rate represents a conservative value, based on the ISRI survey of metal shredders that conducted air emission tests on their mill fume control systems.

Table 34 summarizes the PM emission data from nine source emission tests conducted on mill "defumers" (a.k.a. fume control systems) [ISRI, 1998]. The systems tested included dry shredders having no mill water injection, and damp shredders with mill water injection to reduce fugitive dust, but not to result in excess water flow out of

Table 34 PM emission data from nine source emission tests conducted on a variety of shredder fume control systems [ISRI, 1998]

Type of Fume Control System	Feed Mix	Proportion of Auto Bodies in Feed Mix (%)	Mill Type	HP	Feed Rate (tonnes/hr)	PM (kg/hr)	PM (g/tonne)	Data Source
Defumer without Controls	75% Auto Bodies* + 25% Mixed Scap/White Goods	75%	Dry	n.a.	136.4	0.18	1.33	Table D-10.F
Defumer with Cyclone, Venturi Scrubber and Demister	50% Auto Bodies* + 50% Sheet Iron/White Goods	50%	Dry	3500	54.5	0.36	6.53	D-10.B.1
Defumer with Cyclone, Venturi Scrubber and Demister	20% Auto Bodies* + 80% Sheet Iron	20%	Dry	3500	36.4	0.35	9.75	D-10.B.2
Defumer with Cyclone, Venturi Scrubber and Demister	90% Auto Bodies* + 10% Mixed Scap	90%	Dry	n.a.	60.5	0.85	13.96	D-10.C
Defumer with Cyclone, Venturi Scrubber and Demister	80% Auto Bodies* + 20% Sheet Iron	80%	Dry	n.a.	105.9	2.13	20.13	D-10.E
Defumer with Cyclone, Cyclonic Scrubber	Mixed Scrap		Dry	n.a.	55.5	0.65	11.62	D-10.G
Defumer with Cyclone, Venturi Scrubber and Demister	60% Auto Bodies* + 40% Sheet Iron	60%	Damp	n.a.	90.9	0.50	5.45	D-10.D.1
Defumer with Cyclone, Venturi Scrubber and Demister	60% Auto Bodies* + 40% Sheet Iron	60%	Damp	n.a.	90.9	0.11	1.17	D-10.D.2
Defumer with Cyclone, Venturi Scrubber and Demister	100% Auto Bodies*	100%	Damp	4000	154.5	0.93	6.00	D-10.A

the mill [ISRI, 1998]. One of the nine systems had fume collection but no controls. The other defumer systems included controls consisting of a combination of cyclone air classifiers and downstream scrubbers (*i.e.,* venturi- or cyclonic- style scrubber) with a demister typically present.

The shredder fume control system PM emission data (kg/hr) is presented in Figures 38 and 39, plotted against shredder feed rate (tonnes/hr) and percent auto bodies in the shredder feed mix, respectively. In Figure 38, no significant correlation could be identified between the mill feed rate (tonnes/hr) and the particulate emission rate (kg/hr). It was noted, however, that particulate emissions may vary relative to the quality - specifically the cleanliness - of the shredder feed mix [ISRI, 1998]. This relationship is suggested by the linear regression trendline in Figure 39. A larger dataset would be required to confirm this relationship. Considering the shredding system represented in this research uses damp shredding conditions and a shredder feed mix of approximately 50% auto bodies and 50% mixed loose clips, a PM emission rate of 0.50 kg/hr or 0.14 g/sec has been assumed to estimate the shredder fume control system emissions (see Appendix D, Calculation Methodology).

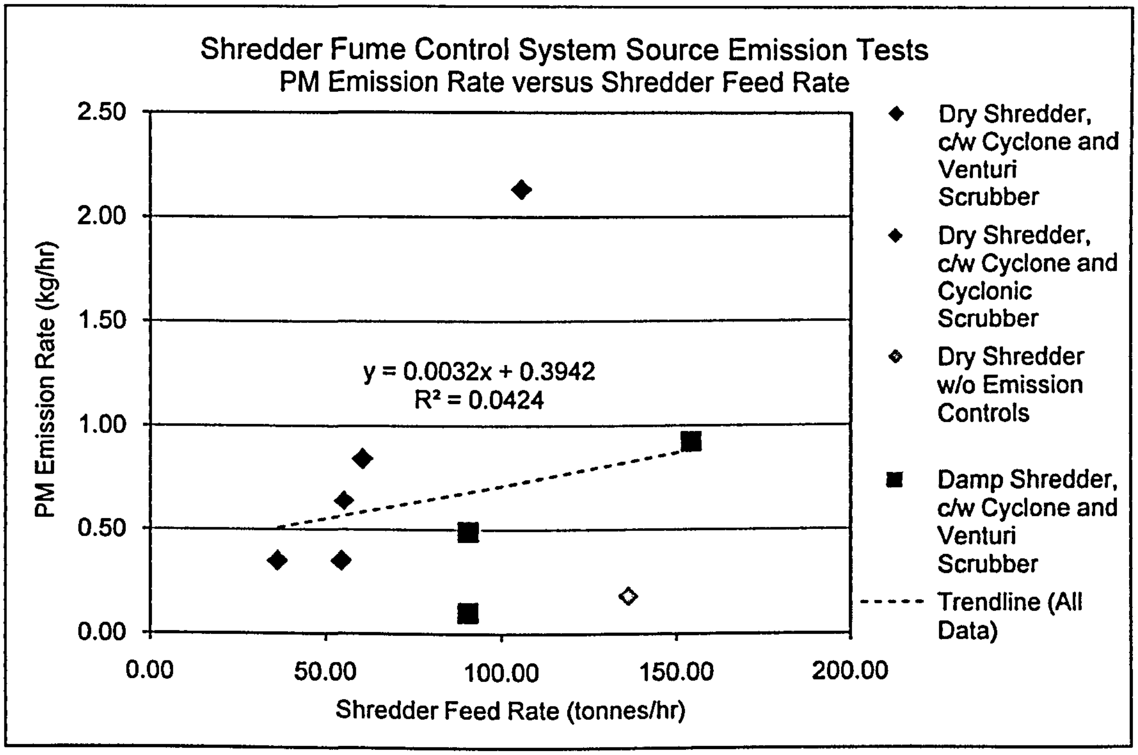


Figure 38 PM emissions (kg/hr) from shredder fume control system source emission tests plotted as a function of shredder feed rate (tonnes/hr).

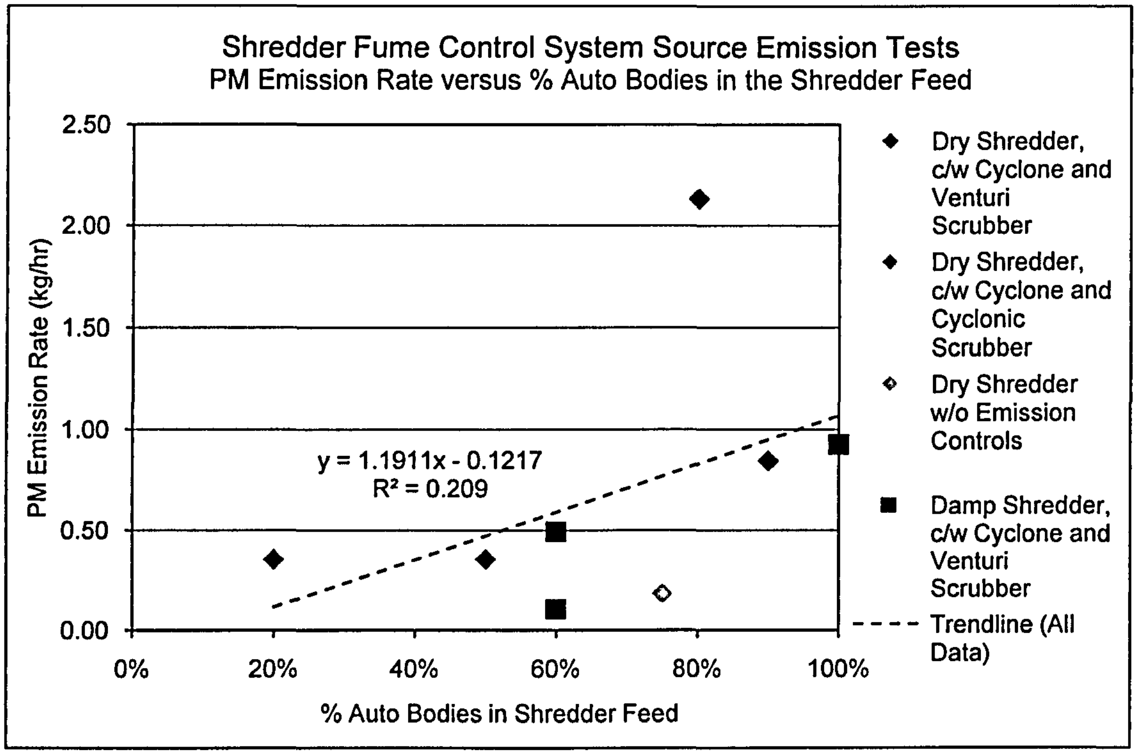


Figure 39 PM emissions (kg/hr) from shredder fume control system source emission tests plotted as a function of % auto bodies in the shredder feed mix.

PM emissions for the downstream material/air separation system have been calculated based on an actual emission rate of 2.02 kg/hr or 0.56 g/sec (± 0.04 g/sec), which represents the average of measurements from two source emission test runs conducted on a Z-box separator system for a damp shredder operating at a feed rate of 164 tonnes/hr. This measured value, although representative of the subject system, appears proportionaly greater than the emission rates measured for similar downstream materials/air separation systems that were surveyed by ISRI [1998]. In the ISRI survey of metal shredder emissions tests [1998], results were available for five emissions tests conducted on downstream material/air separation systems.

Table 35 summarizes the PM emission data from these five source emission tests presented in the ISRI survey [ISRI, 1998]. The separation systems that were tested all consisted of Z-box separators (*i.e.*, vertical air classifiers) in closed-circuit systems with cyclone separators, air recirculation fans and air "bleed-offs".

Table 35 PM emission data from five source emission tests conducted on a z-box based material/air separator systems [ISRI, 1998]

Type of Material/Air Separation System	Feed Mix	Proportion of Auto Bodies in Feed Mix	Mill Type	HP	Feed Rate		PM		Data Table in ISRI, 1998
		(%)			(Tons/hr)	(tonnes/hr)	(g/sec)	(kg/hr)	
Z-Box Separator with Cyclone & Bleed-off	100% Auto Bodies	100%	Damp	4000	185.0	168.2	0.134	0.482	D-11.A
Z-Box Separator with Cyclone & Bleed-off	50% Auto Bodies + 50% Sheet Iron/White Goods	50%	Dry	3500	60.0	54.5	0.032	0.114	D-11.B.1
Z-Box Separator with Cyclone & Bleed-off	20% Auto Bodies + 80% Sheet Iron	20%	Dry	3500	40.0	36.4	0.002	0.007	D-11.B.2
Z-Box Separator with Cyclone & Bleed-off	90% Auto Bodies + 10% Mixed Scap	90%	Dry	n.a.	66.6	60.5	0.107	0.386	D-11.C
Z-Box Separator with Cyclone & Bleed-off	80% Auto Bodies + 20% Sheet Iron	80%	Dry	n.a.	116.5	105.9	0.202	0.727	D-11.E

Figures 40 and 41 illustrate the Z-box separator system PM emissions (kg/hr) plotted against shredder feed rate (tonnes/hr) and percent auto bodies in the shredder feed mix, respectively, for both the ISRI surveyed systems and the additional damp shredder, Z-box separator system. Figure 40 includes trendlines representing the proposed linear correlation between the PM emission rate and shredder feed rate for the ISRI survey data alone and for all data combined. As indicated by the trendline equations and their corresponding R-squared values, a potential correlation between PM emission rate and shredder feed rate is suggested, particularly when all the data is considered. A correlation is also suggested between shredder feed quality and PM emissions for the ISRI data survey, as plotted in Figure 41. However no correlation is apparent between shredder feed quality and PM emissions when all the data is considered. A larger dataset would be required to confirm if there is a bona-fide relationship between Z-box separator system PM emissions and either the shredder feed rate or the feed quality.

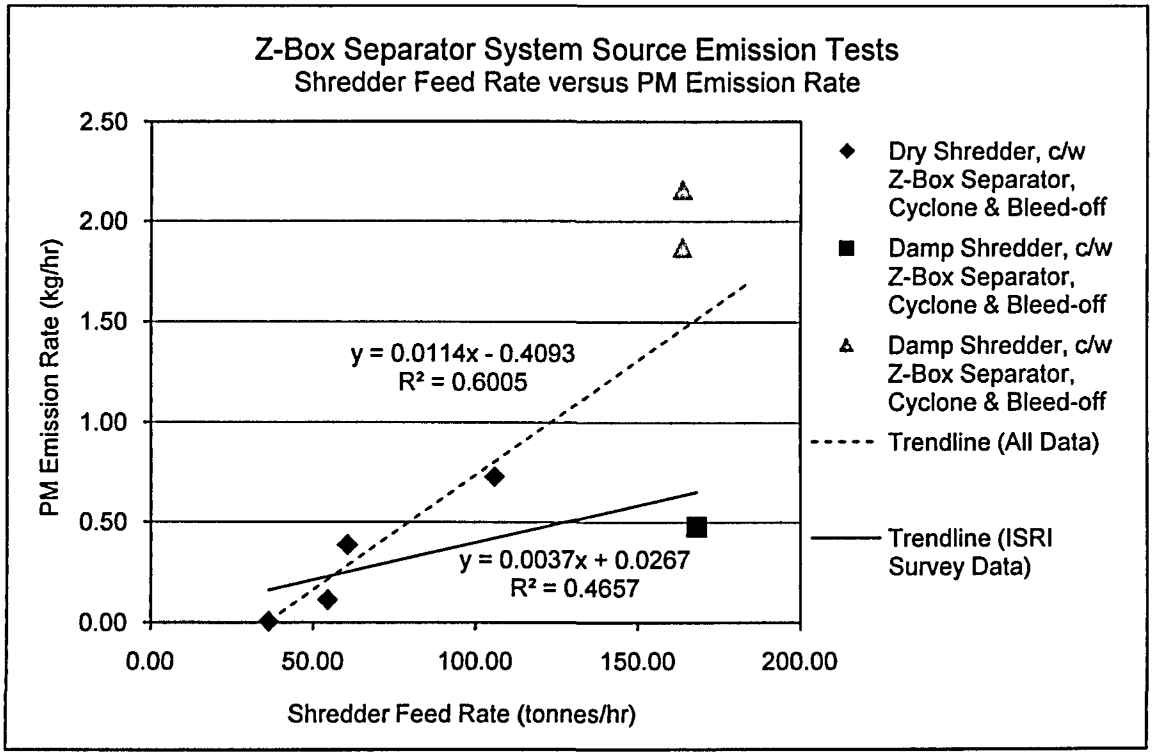


Figure 40 PM emissions (kg/hr) from z-box separator system source emission tests plotted as a function of shredder feed rate (tonnes/hr).

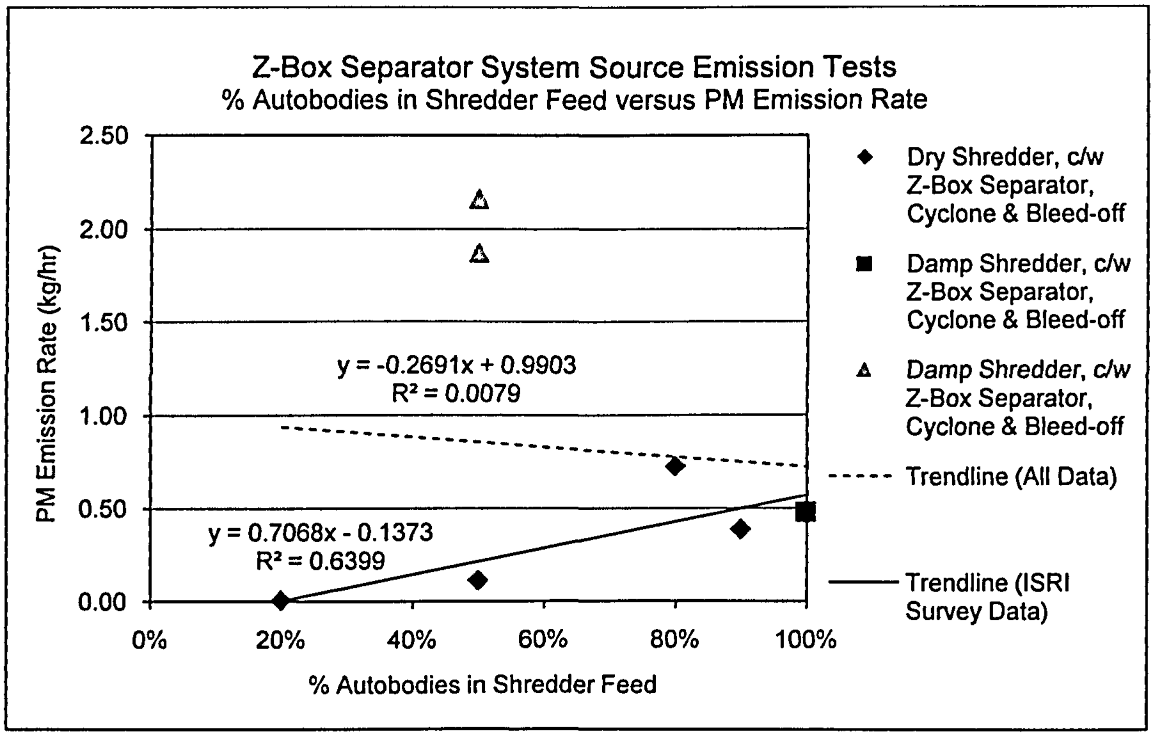


Figure 41 PM emissions (kg/hr) from z-box separator system source emission tests plotted as a function of % auto bodies in the shredder feed mix.

Table 36 summarizes the estimated PM emissions from the shredder air emission control systems, the shredder fume control and material/air separation systems (refer to Appendix D, Calculation Methodology for details).

Table 36 Estimated PM emissions generated by the shredder air emission control systems

Air Emission Control System	PM (g/tonne of shredder feed)
Shredder Fume Control	3.4
Material/Air Separation System	12.3
Total	15.7

6.3 Quality Analysis/Quality Control

Although this LCI is based on data from only one dismantler and one shredder, this normalized case-study provides a baseline of the rates of parts and material recoveries that are typical of the dismantling and shredding processes in North America. To understand just how "typical" these rates of recoveries are or how much they may vary from facility to facility, additional case studies will be required of multiple facilities. The dismantling recoveries established in this base line study are based on the assumption that one HSELV is retired and processed for every 7-8 LSELVs. For dismantlers that process only HSELVs, parts and/or materials recoveries for reuse, remanufacture and "pre-shredder" recycling may be greater per tonne ELVs processed compared to this case. In contrast, for facilities that principally process LSELVs parts and materials recoveries for reuse, remanufacture and "pre-shredder" recycling will likely be less than what was found in this case study; more materials will be directed for shredding and metals recovery. Besides identifying by how much the rates of parts and materials recoveries vary by facility, it will be important to determine what proportion of vehicles in the North American "ELV fleet" are processed annually as HSELVs versus LSELVs.

As previously discussed on Section 6.1.2.6 ELV Hulks and Parts Shipped for Shredding, the difference between the actual and estimated quantities of ELV hulks, deleted parts and CORE parts shipped for shredding is 6.5%. This error is suspected to be to due to (1) an under estimation of the mass of the ELVs entering the dismantling process and (2) an over estimation of the mass of parts and fluids recovered and directed for reuse, remanufacturing and recycling. The uncertainties that have been introduced into this analysis are a consequence of the following different types of data and methods used to translate vehicle counts and part counts into vehicle and parts mass flows:

1) To estimate the mass flow of ELVs into the dismantling process, representative curb weights of several body styles were applied to each ELV entering the dismantling process and averaged to establish an estimated mean curb weight for each vehicle, by vehicle model and model year. This approach was used because vehicle body/trim styling were not known for the majority of the ELVs received and processed (only vehicle model). The uncertainties introduced as a result of this methodology are suggested by the coefficients of variation calculated for the average mean curb weights estimated for the HSELVs and LSELVs by vehicle size class, *i.e.,* 7-16% for HSELVs and 7-21% for the LSELVs (see Tables 17 and 18).
2) Parts weight data obtained from either the Parts Mass Study, from the USCAR VRP disassembled vehicle database, or from internet based sources were used to estimate parts mass flows. Uncertainties may be introduced into this analysis as a consequence of the part weight data coming from different sources.
3) Where it was reasonable to expect HSELV or LSELV part counts to vary with the proportion of vehicles processed by vehicle size class, and part weights to vary with vehicle size, the vehicle part weights from the Parts Mass Study and the part counts were applied to the unit volume percentages of vehicles in the different vehicle size classes to estimate the parts mass flows distributed over the different HSELV or LSELV size classes. The parts mass estimates based on this calculation method tended to result in parts mass estimates that were lower and considered more representative than the parts mass flows estimated by applying the arithmetic averages of the vehicle part weights to the part counts. For example, the estimated mass of HSELV parts recovered and sold for reuse was 1,184,529 kg based on mean part weights, which is higher than the 1,126,824 kg estimate based on parts weights and part counts distributed by vehicle size class, representing a difference of 1.9% weight of the HSELVs processed. Applying the arithmetic averages of the vehicle part weights to the part counts tends to result in parts mass flows that are biased on the high side, which would exacerbate the error between the actual and estimated quantities of ELV hulks, deleted parts and CORE parts shipped for shredding. This effect on the error is

likely because the arithmetic averages do not reflect the proportion of parts recovered from the various vehicle classes taken in by the dismantler.

4) Where the part counts could not be related to the proportion of vehicles processed by vehicle size class, such as for the LSELV parts sold for reuse, parts mass flows were estimated by applying the arithmetic averages of the vehicle part weights from the Parts Mass Study, instead of the part weights distributed over the different vehicle size classes.

7 DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

7.1 Major Findings and Conclusions

7.1.1 VEOL Parts/Materials Reuse, Remanufacture and Recycling

Figures 42 and 43, respectively, graphically illustrate the inputs and outputs from the ELV dismantling process (excluding CORE parts). ELVs input to the dismantling process consisted of approximately 867.6 kg of LSELVs and 132.4 kg of HSELVs per tonne ELVs processed annually (86.7% weight versus 13.3% weight, respectively). As much as 116.3 kg/tonne (11.6% weight) of the ELVs entering the dismantling process are recovered and directed for either, reuse, remanufacturing or recycling, including the recovered fluids. Parts recovery for reuse includes parts from both LSELVs and HSELVs: 8.1 kg/tonne (0.8% weight) and 48.9 kg/tonne (4.9% weight) of ELVs processed, respectively. The remaining 883.7 kg/tonne (88.4% weight) of ELVs entering

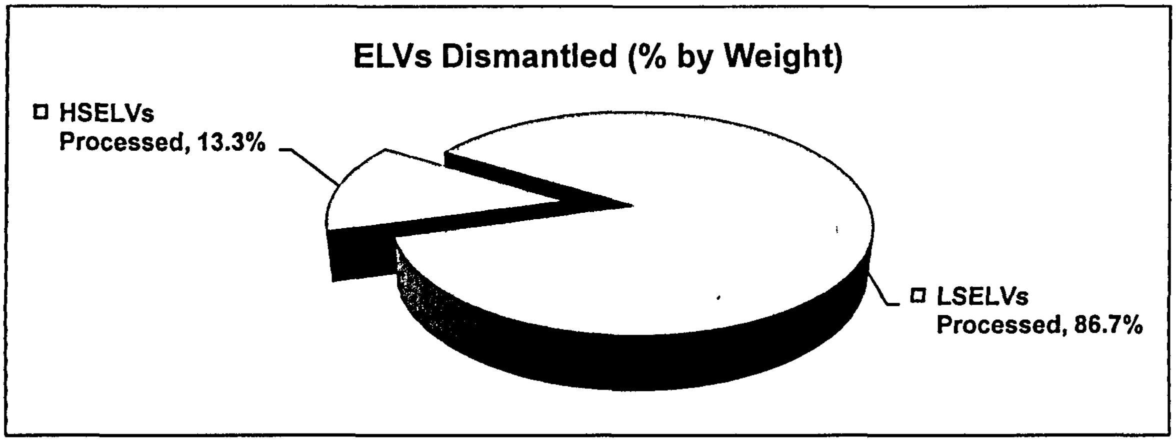


Figure 42 ELVs input to the dismantling process.

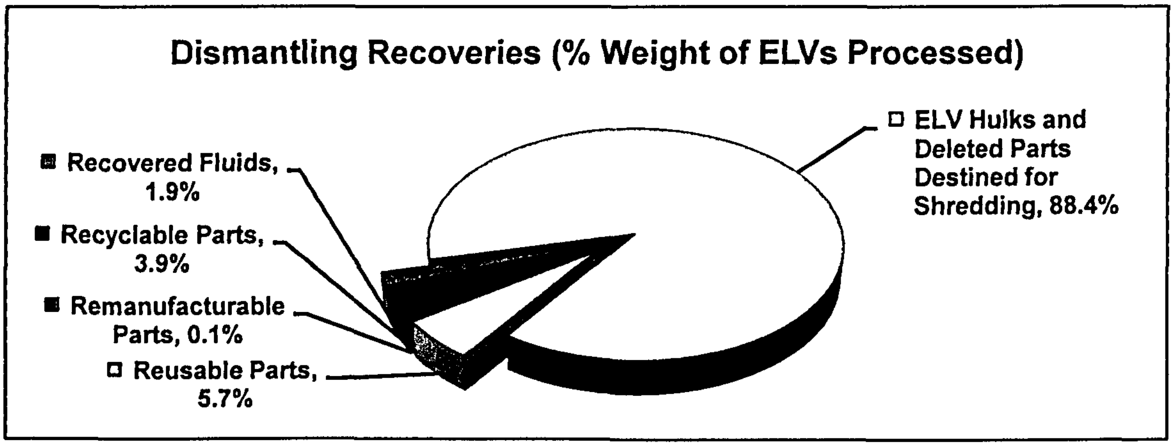


Figure 43 Dismantling process outputs.

the dismantling process are leftover ELV hulks and "scrapped-out" parts that are directed for shredding. It should be noted that the dismantling recoveries identified in Figure 43 are based on the assumption that 1 HSELV is retired and processed for every 7 or 8 LSELVs processed or for every tonne of HSELVs processed approximately 6.5 tonnes of LSELVs are processed.

As illustrated in Figure 44, leftover ELV hulks and "scrapped-out" parts represent 576.0 kg/tonne (57.6% weight) of the materials processed by the participating shredder facility. The balance of the shredder feed materials consist of other oversized, metals-rich scrap, such as appliances, demolition and construction scrap. Figure 45 illustrates the outputs from the shredding process. As much as 775 kg/tonne (77.5% weight) of the shredder feed materials are recovered in the shredded ferrous product, another 33 kg/tonne (3.3% weight) are recovered in the non-ferrous residue and the balance, 192

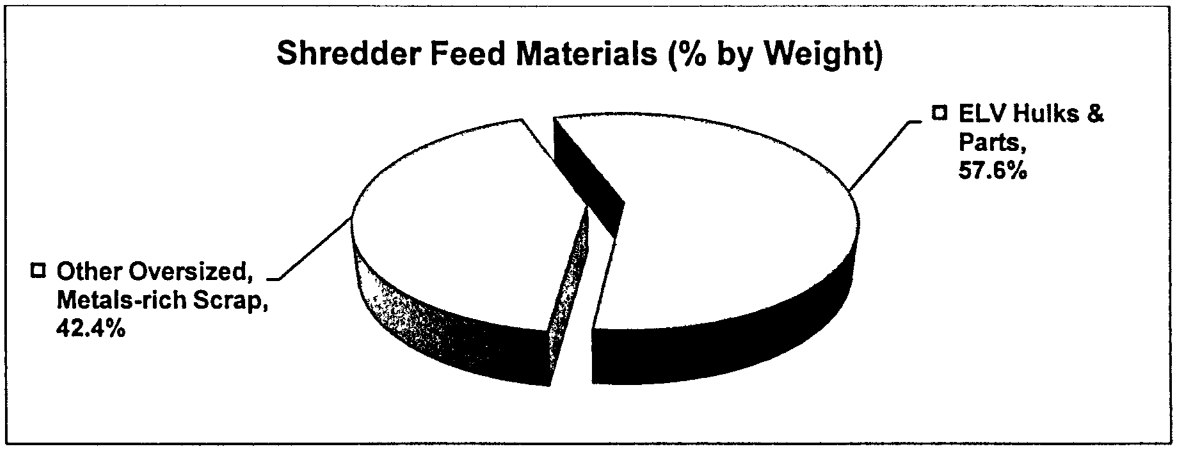


Figure 44 Shredding process inputs.

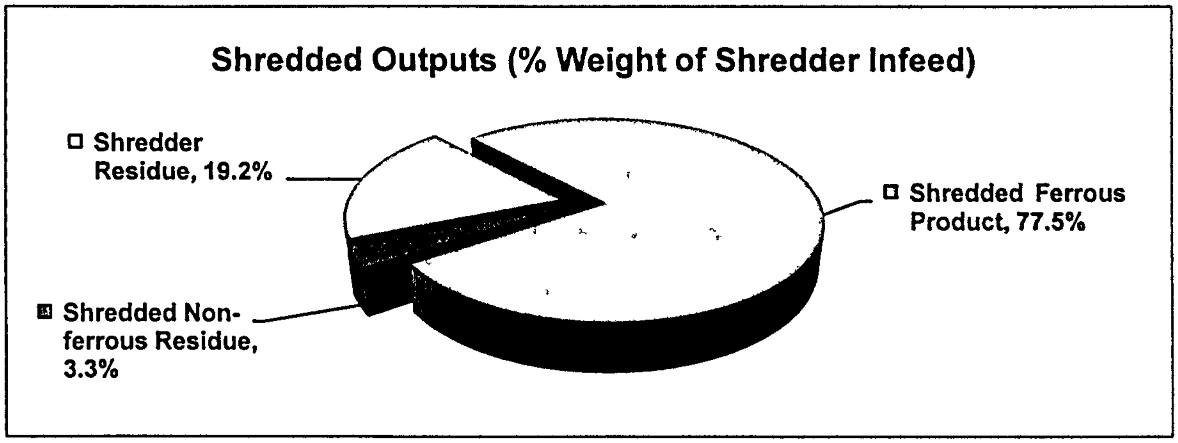


Figure 45 Shredding process outputs.

kg/tonne (19.2% weight) is accounted for in the shredder residue.

Based on the data presented herein, the proportions of shredded ferrous metals, non-ferrous metals and shredder residue generated relative to the amount of vehicles entering the end-of-life phase, *e.g.,* per tonne of ELVs retired, could not be determined because the materials make-up of the ELV hulks and parts in the shredder feed stream is unknown. However, as part of future investigations, the parts materials compositions determined during the Parts Mass Study may be used for this purpose.

By applying the parts materials compositions from the Parts Mass Study to the parts mass flows calculated in this research, material mass flows (for example, kg metals and non-metals/tonne ELVs retired) may be estimated for the parts directed for reuse, remanufacturing and recycling, as well as for the leftover ELV hulks and parts directed for shredding. These estimations would include the proportions of ELV materials that are recovered and/or lost in the shredded metal products and the shredder residue relative to the ELVs hulks and parts directed for shredding (*i.e.,* in kg/tonne ELV hulks and parts shredded) and more importantly, relative to the vehicles entering the end-of-life phase (*i.e.,* in kg/tonne ELVs dismantled).

By assessing the proportions of materials recovered from ELVs and directed for reuse, remanufacturing, pre-shredder recycling and post-shredder recycling, North American ELV management system and recycling rates may be benchmarked against legislated ELV management practices and recycling rates used in other countries, such as those dictated under the EU ELV Directive 2000/53/EC [EU, 2000] or Japan's 2002 ELV Recycling Law.

The results of this research will be of value to North American policy makers, should similar legislation be considered for the management of ELVs in Canada and the US. For example, under the Article 2(a) of the EU ELV Directive, EU Member States have been required to take measures to ensure that, by 1 January 2006, on average at least 80% of ELV materials by weight are reused and recycled and 85% go for reuse and recovery (including energy recovery) [EU, 2000]. By establishing a benchmark of North American ELV recycling rates, this research will help policy makers to understand, for the first time, how effective the existing market-driven ELV management system in North America would be to meet ELV recycling targets without legislation.

7.1.2 VEOL Energy and Water Usage

With respect to energy input, 23.1 kW-hr of electricity was consumed per tonne of ELVs processed by dismantling and 28.8 kW-hr per tonne of materials processed by shredding. As illustrated in Figure 46, electrical energy consumption in the shedding process is relatively constant and does not vary significantly with shredder feed material type. In fact, the average electrical energy inputs per tonne of ELV hulks and parts shredded, and per tonne of other oversized, metals-rich scrap shredded were 28.7 and 29.0, respectively.

Electrical energy input to the shredding process did not vary significantly with shredder feed rate except in the month of December when shredder feed rate dropped to very low levels and, consequently, electrical power usage increased to 45.2 kW-hr per tonne. The shredding system requires an initial threshold amount of electrical energy (kW-hr) to operate at idle. This initial amount of energy is required to overcome mechanical inertia, resistances and losses, and can represent a significant percentage, 17% for example, of the maximum energy required to operate the system at the shredder's maximum design feed rate. As materials are fed into the shredder, an additional amount of electrical energy will be consumed for every tonne of material processed, but overall the efficiency of the shredding system increases. If the total amount of materials shredded in a month is significantly low, as the case for the month

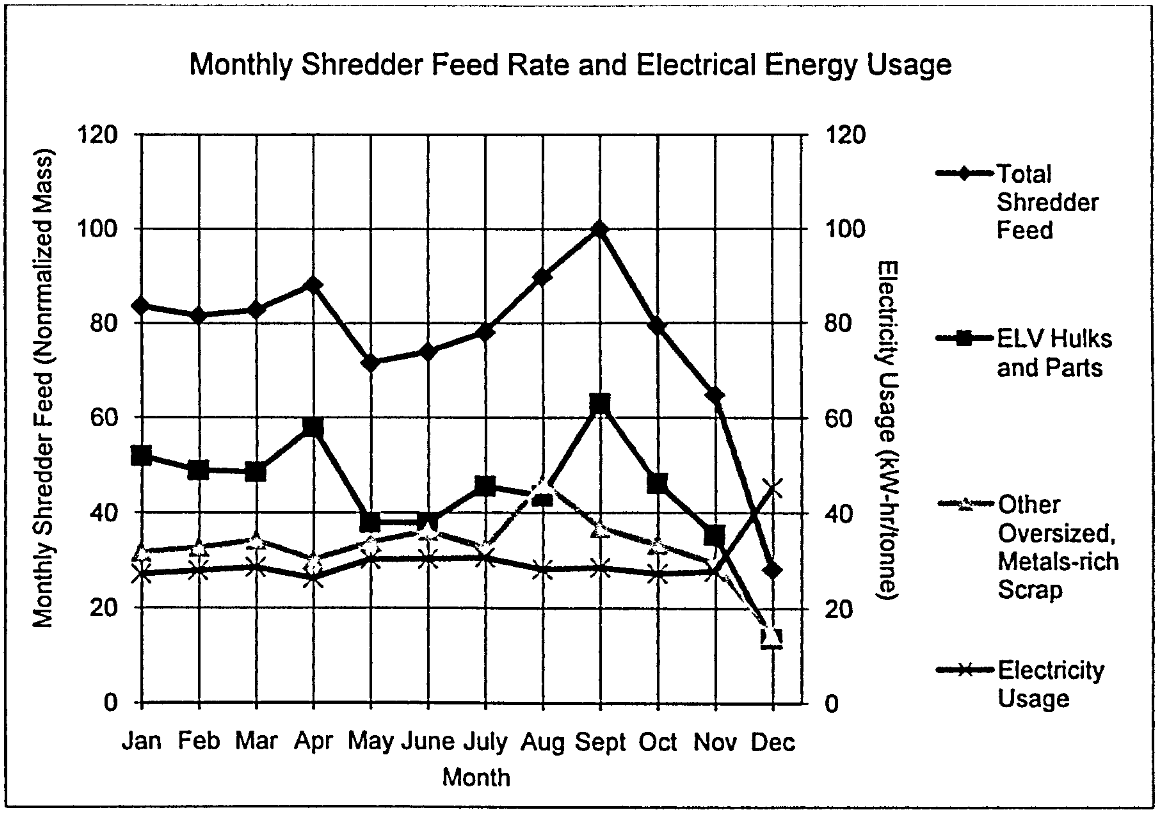


Figure 46 Monthly shredder feed (normalized mass) and electricity usage.

of December, the electrical energy consumption averaged over the tonnes processed will be greater.

Considering that electrical energy consumption in the shredding process appears independent of the material type, it is reasonable to assume that the electrical consumption per tonne of shredded material will be approximately the same whether the materials are stripped ELV hulks and parts or other metals-rich scrap or whole ELVs, meaning:

$$\frac{kW\text{-}hr\ Electrical\ Energy}{tonne\ Shredder\ Feed} \cong \frac{kW\text{-}hr\ Electrical\ Energy}{tonne\ ELV\ Hulks + Parts} \cong \frac{kW\text{-}hr\ Electrical\ Energy}{tonne\ Other\ Metals\text{-}rich\ Scrap} \cong \frac{kW\text{-}hr\ Electrical\ Energy}{tonne\ Whole\ ELVs} \quad [18]$$

Accordingly, the total electrical energy required for ELV dismantling and shredding per tonne of ELVs entering the VEOL process may be approximated by the sum of the two electrical energy inputs and therefore, is estimated to be nearly 50 kW-hr/tonne ELVs entering VEOL.

Water use in the shredding process is estimated to be almost 6 liters per tonne of shredder feed. Neither water consumption nor waste water outputs (*i.e.,* oil/water separator sludge from closed-circuit parts washing systems) could be accounted for in the dismantling process due to lack of available data.

7.1.3 VEOL Air Emissions

Figure 47 summarizes the VEOL air emissions estimated in this research. The total CO_2, SO_2, and NO_X (as NO_2) air emissions generated as a result of electrical energy use in the VEOL process are each estimated by summing the emissions estimated for the dismantling and shredding processes. As previously discussed, the electricity used in the shredding process per tonne of shredded material will be approximately the same whether the materials are stripped ELV hulks and parts, or whole ELVs. Similarly, the air emissions generated due to electrical energy use per tonne of shredded ELV hulks and parts should be approximately equal to the air emissions generated due to electrical energy use per tonne of whole ELVs shredded. Hence, an estimated 16 kg CO_2, 58 g SO_2, and 20 g NO_X (as NO_2) are emitted as a consequence of electrical energy generation and use per tonne of ELVs entering VEOL.

Only total particulate matter (PM) emissions from shredding air emissions control systems could be accounted for in this research. Approximately 16 g PM are emitted per tonne of shredder feed.

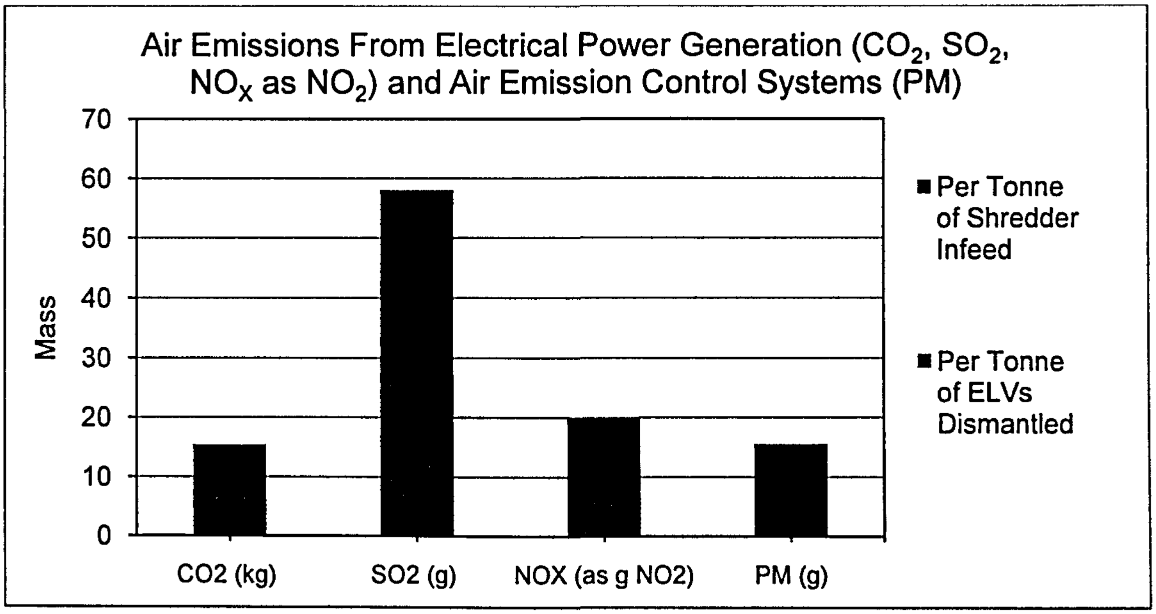


Figure 47 VEOL Air Emissions.

Due to a lack of readily available data, the following air emissions and sources were excluded from the LCI:

1) CO_2, CO, SO_2, NO_X, PM, and HC emissions from diesel combustion sources, for example, comfort heating systems and highway or off-road diesel fueled vehicles;
2) CO_2, CO, SO_2, NO_X, N_2O and VOC emissions from natural gas combustion sources, principally comfort heating systems;
3) CO_2, CO, SO_2, NO_X, and PM emissions from residual oil combustion sources, principally comfort heating systems; and
4) fugitive PM emissions from on-site vehicle traffic.

7.1.4 HSELVs, LSELVs and Potential for "Planned Vehicle Obsolescence"

Table 37 summarizes the characteristics of the HSELVs and LSELVs processed in 2005. The HSELVs averaged 7 years in age and 1522 kg by weight. The LSELVs averaged 15 years in age and 1343 kg by weight.

Figures 15, 26, and 32, in Chapter 6, respectively illustrate, the HSELV counts, the HSELV reusable part counts, and HSELV deleted part counts aggregated and plotted by vehicle model year. It can be argued that these graphs represent "supply and demand" curves for higher value automotive parts.

The HSELV counts in Figure 15 represent the supply of vehicles available to dismantlers for recovery of parts for reuse, as well as for remanufacturing and post-

Table 37 Characteristics of ELVs processed in 2005

		HSELVs	LSELVs
Vehicles Represented By ELVs Processed in 2005	Number of Makes	37	49
	Number of Models	213	240
	Range of Model Years	1986-2005	1963-2004
	Mean Model Year	1998	1990
	Average Age	7-year old ELVs	15-year old ELVs
	Average Vehicle Curb Weight	1522 kg	1343 kg

shredder recycling. The greatest proportion of these vehicles average approximately 7 years in age, as indicated by an average vehicle model year of 1998 (based on vehicles processed in 2005).

The HSELV part counts in Figure 26 represent the demand for parts sold for reuse, with the greatest proportion of parts being sold for vehicles averaging 7 years in age as indicated by an average vehicle model year of 1998 (based on vehicles processed in 2005). Reusable part sales drop significantly for vehicles slightly older and younger than this potentially "optimum" vehicle age.

The HSELV parts deleted from inventory demonstrate similar trends. As illustrated in Figure 32, the greatest proportion of HSELV parts that were deleted from inventory, and directed for shredding with ELV hulks, were for vehicles averaging 8 years old as indicated by the mean vehicle model year of 1997 (for vehicles processed in 2005). This implies that the length of time that parts, for a particular vehicle model year, may be retained in inventory and available for resale, is, on average, relatively short – approximately one year. However, to confirm this speculation, more data analysis would be required to (1) understand what proportion the deleted parts represent of the total parts retained in inventory, for a particular vehicle model year and (2) determine if this inventoried parts retention time remains consistently short from one year to the next for any vehicle model year.

Interestingly, these trends may suggest an optimum dismantling scheme, using "planned" or anticipated vehicle obsolescence: ELVs of an "optimum" average age range of between, for example, 5 and 9 years are targeted as HSELVs, so parts recovery and sales may be maximized for direct reuse and remanufacturing. Older vehicles would be targeted as LSELVs and principally directed for materials recovery and recycling. The potential benefits of such an ELV management scheme would be the:

1) maximization of parts/materials reuse, which is, in the 4-R's hierarchy, preferred to parts/materials recycling or energy recovery;
2) maximization of the economic returns to the dismantling industry; and
3) reduction in air emissions by decreasing the number of older, less fuel-efficient vehicles on the road.

7.1.5 Establishing the LCI

The approach used to develop this LCI can be used as a template for establishing how to undertake LCIs for other end-of-life complex products, such as end-of-life appliances (ELAs). Case studies of end-of-life management schemes used for other types of complex products may be performed to identify the practices and/or unit operations used in the systems as well as systems inputs and outputs. Unit volume product quantities, by product type (*e.g.,* refrigerators, stoves, microwave ovens, dishwashers, etc.) applied to typical product weights and compositions (by product type) could be used to translate product counts into the products and/or material mass flows into and/or out of the system. In particular, the methods employed in this body of research may be valuable in assisting other LCA practitioners by providing examples of how to overcome data gaps, resolve data inconsistencies, and how to practically obtain data or set up data acquisition schemes in the field through interactions with industry partners.

7.2 Contributions

The research described in this thesis has contributed to engineering knowledge by providing the most comprehensive analysis, to-date, of the structure of the ELV management system typically found in North America. It also demonstrates how LCA methods may be applied to a product's end-of-life phase, starting with construction of a LCI, to better understand the environmental burdens associated with end-of-life processes. Although a significant portion of the data used in this research comes from one dismantling facility, the data has been augmented significantly from several other information sources. The research has focused further on practices common to the industry. While the resulting parts and mass flows will not be universally applicable to every dismantling operation, they are representative and form a comprehensive starting point for any additional analysis.

This research provides the following specific contributions to the automotive recycling industry:

1) The case studies conducted in this research allowed for the development of a comprehensive LCI of the North American VEOL process, consisting of ELV dismantling and shredding. Life Cycle Impact Assessment methods may be applied to this normalized "base case" LCI in future research efforts to identify the associated environmental impacts (*e.g.,* resource consumption/recovery; global warming due to GHG emissions; atmospheric acidification; health and ecotoxicity).
2) This research identifies two relatively distinct groups of ELVs that are retired and managed by dismantlers, high-salvage ELVs (HSELVs) and low-salvage ELVs (LSELVs). The research characterizes the average vehicles currently being managed in these two ELVs groups, according to weight, vehicles size class, and age, and may suggest an optimum dismantling scheme, using "planned" or anticipated vehicle obsolescence.
3) The Parts Mass Study conducted as part of this research included the assessment of the weights and materials compositions of over 850 parts (collected from 49 different vehicles of known vehicle make, model and model year), representing 307 unique part-types. These part-types are representative of what typical North American dismantlers seek and produce. Using this parts mass information, the mass flows, in kg/tonne HSELV and/or LSELV processed by dismantling, have been estimated for the following parts and materials, as illustrated in Figure 48:
    a. 62 CORE part types recovered and directed for reuse or metals recovery and recycling via shredding with ELV hulks;
    b. 151 HSELV part types recovered and sold for reuse;
    c. Over 598 LSELV part types recovered (via a self-service "UPIC" facility) and sold for reuse;
    d. 6 part types, recovered principally from HSELVs, and sold for remanufacturing;
    e. 5 part types recovered both HSELVs and LSELVs and sold for pre-shredder recycling;

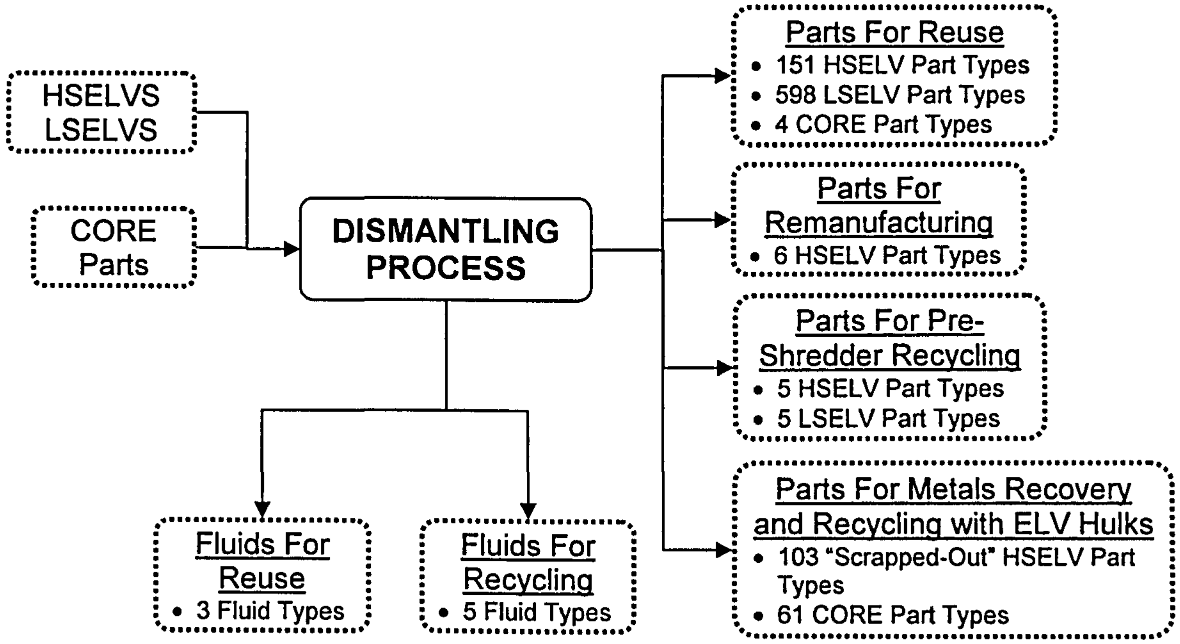


Figure 48 Flowchart illustrating parts and materials recovered from ELVs and directed for reuse, remanufacture, pre-shredder recycling, and for metals recovery and recycling with ELV hulks.

   f. 8 types of fluids recovered from both HSELVs and LSELVs and sold for reuse or recycling; and
   g. 103 HSELV part types deleted from inventory ("scrapped-out") and directed for metals recovery and recycling via shredding with ELV hulks.

4) This research identifies the efficiencies and inefficiencies of the dismantling process in terms of overall parts mass flows per tonne of ELVs entering VEOL. As much as 11.6% weight of the ELVs entering the dismantling process are recovered and directed for either, reuse, remanufacturing or "pre-shredder" recycling. The other 88.4% weight of the ELVs entering the dismantling process are the leftover ELV hulks and "scrapped-out" parts directed for shredding, and include parts and materials that are not recovered by the dismantler and directed for reuse, remanufacture or pre-shredding recycling. The non-recovered materials may represent "missed opportunities".
5) This research identifies the efficiencies and inefficiencies of the shredding process in terms of overall materials mass flows per tonne of shredder infeed, *i.e.*, mixture of 57.6% weight ELV hulks and parts, and 42.4% weight of other oversized, metals-rich scrap. As much as 77.5% weight of the shredder infeed is recovered in the shredded ferrous product and another 3.3% weight in the non-ferrous residue which are subsequently directed for metals recycling. The other

19.2% weight of the shredder infeed ends up in the shredder residue and is typically directed for landfill disposal.

6) This research accounts for (1) electrical power input to the VEOL process (in kW-hr/tonne of ELVs processed), (2) water input to the shredding process (in l/tonne of shredder infeed), (3) CO_2, SO_2, and NO_X (as NO_2) emissions, generated as a result of electrical energy use in the VEOL process (in kg or g per tonne of ELVs processed), and (4) PM emissions emitted from shredder air emissions control systems (in g/tonne of shredder infeed).
7) From a life cycle methodology perspective, this research provides a basis for classifying, estimating, and assessing the dismantled "assemblages" of parts and their characteristics at the end-of-life phase. The research shows that these dismantled assemblages are distinct from the manufacturing phase and reflect the reality that few products (if any) can be fully reverse assembled. Furthermore, enhancing the recovery and recycling of materials from complex products, such as automobiles, will likely not result from disassembling an item the way it was produced, but from optimizing various unit processes that work together and exploiting hidden opportunities revealed through an LCA.

7.3 Future Work

The following are recommended areas for further work as a consequence of the findings of this research:

1) To expand upon the VEOL LCI summarized herein, the parts materials compositions from the Parts Mass Study should be applied to the parts mass flows calculated in this research to establish:
    a. the material mass flows, as metals and non-metals, for the parts directed for reuse, remanufacturing and recycling, as well as for the leftover ELV hulks and parts directed for shredding (for example, kg metals and non-metals/tonne ELVs retired), and subsequently;
    b. estimate the proportions of ELV materials, as metals and non-metals, that are recovered and/or lost in the shredded metal products and the shredder residue relative to the ELVs hulks and parts directed for shredding (*i.e.*, in kg/tonne ELV hulks and parts shredded) and more importantly, relative to the vehicles entering the end-of-life phase (*i.e.*, in kg/tonne ELVs dismantled).

This information can then be used to benchmark current North American ELV management systems and recycling rates against legislated dismantling practices and recycling rates used in other countries, such as those dictated under the EU ELV Directive 2000/53/EC or Japan's 2002 ELV Recycling Law.

2) To refine this "base case" VEOL LCI, it is recommended that a broader vehicle parts weight sample set, such as the VRDC vehicle data set, be used to improve the dismantled parts and materials mass flow estimates.
3) Certain environmental burdens associated with particular ELV management activities or processes were scoped out of this VEOL LCI due to time constraints, limitations in the scope of the research and the lack of readily available data. To construct a more complete and representative LCI/LCA of the VEOL management system used in North America, data should be obtained and analyzed to evaluate the eco-efficiencies of the following relevant activities and processes:
    a. ELV shipment to dismantlers, *i.e.,* fuel inputs and associated air emissions;
    b. ELV hulks and parts shipment to shredders, *i.e.,* fuel inputs and associated air emissions;
    c. Fuel usage in the dismantling process for comfort heating and on-site vehicle operation, *i.e.,* fuel inputs and associated air emissions;
    d. Parts washing systems used in the dismantling process, *i.e.,* water input and oil/water separator sludge generated in the process;
    e. On-site vehicle traffic at the dismantler, *i.e.,* fugitive emissions from off-road mobile sources;
    f. Fuel usage in the shredding process for on-site vehicle operation, *i.e.,* fuel inputs and associated air emissions;
    g. On-site vehicle traffic at the shredder, *i.e.,* fugitive emissions from off-road mobile sources; and
    h. Shipment of the shredded metals products and waste for recycling or disposal, *i.e.,* fuel inputs and associated air emissions.
4) The dismantling procedures and workflow video recorded during the Parts Mass Study should be reviewed and analyzed. This information could then used with the results of the VEOL LCI research (*e.g.,* "scrapped-out" HSELV part types) to

identify and review potential opportunities for enhanced materials recovery for "post-dismantling/pre-shredder" recycling.

5) Life cycle impact assessment (LCIA) methods should be applied to the VEOL Base Case, *i.e.,* Full Dismantling + Shredding, to identify the environmental impacts associated with these ELV management processes, *e.g.,* resource consumption/recovery, global warming due to GHG emissions, atmospheric acidification, and health and excotoxicity.
6) Using LCA methods, the impacts due to the VEOL Base Case, Full Dismantling + Shredding, should be compared to the impacts due to alternative ELV management strategies, such as Minimal Dismantling. An example of the latter would be to recover only fluids and hazardous materials, followed by shredding.
7) Using LCA methods, the regional differences between dismantlers parts recovery schemes and recovery rates can be compared. Identifying the differences between dismantlers recovery schemes will allow researchers to:
    a. understand the variability of the parts recovery schemes, and recovery rates from one region to another;
    b. identify the reasons for the differences (*e.g.,* market supply and demand) and based on this knowledge; and
    c. identify potential opportunities to optimize and enhance parts recovery, for reuse, remanufacturing and pre-shredder recycling.
8) A study is recommended to evaluate unit cost to produce recyclable materials (metals in particular) and non-recyclable materials from ELVs, via dismantling and shredding to estimate the cost as $/tonne ELVs entering VEOL.
9) Given that shredder feed materials can include a significant proportion of other oversized metals-rich scrap besides ELV hulks and parts, and the composition of this feed stream and its variability not well understood, a study is recommended to evaluate and characterize the materials composition of this alternative shredder feed material.
10) A study is recommended to determine the proportion of vehicles in the North American "ELV fleet" that are processed annually as HSELVs versus LSELVs.

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APPENDIX A Letter(s) of Permission to Use SAE Copyrighted Material

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Susan

Susan Sawyer-Beaulieu, M.A.Sc., B.Sc., B.A., P.Eng., Ing
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Publication title/full citation	Dissertation Chapter
Sawyer-Beaulieu, Susan and Edwin K.L. Tam, Applying Life Cycle Assessment (LCA) to North American End-of-Life Vehicle (ELV) Management Processes, SAE Technical Paper Series, 2005-01-~~1283,~~ 0846 2005 SAE World Congress, April, Detroit Michigan.	Chapter 2
Sawyer-Beaulieu, Susan and Edwin K.L. Tam, Constructing a Gate-to-gate Life Cycle Inventory (LCI) of End-of-Life Vehicle (ELV) Dismantling and Shredding Processes, SAE Technical Paper Series, 2008-01-~~0846~~, 1283 2008 SAE World Congress, April, Detroit Michigan.	Chapters 3, 4 and 5

Please do not hesitate to contact me should have any questions or require additional information. I look forward to hearing from you at your earliest convenience. Thank you.

With best regards,
Susan

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Publication title/full citation	Dissertation Chapter
Sawyer-Beaulieu, Susan and Edwin K.L. Tam, Analysis of North American End-of-Life Vehicle (ELV) Dismantling and Shredding Practices Using Life Cycle Assessment (LCA), Proceedings of the 9th International Automobile Recycling Congress March 11-13 2009 Munich, Germany	Chapters 3, 4, 5 and 6

Please do not hesitate to contact me should have any questions or require additional information. I look forward to hearing from you at your earliest convenience. Thank you.

Best regards,

Susan

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APPENDIX B Table 38 List of part-types recovered by the participating dismantlers, with corresponding Hollander and Pinnacle part numbers

Table 38 List of part-types recovered by the participating dismantlers with corresponding Hollander and Pinnacle part numbers

Part Types Sold				Part Types Sold			
Part Type Count	Hollander Part No.	Pinnacle Part No.	Part Type	Part Type Count	Hollander Part No.	Pinnacle Part No.	Part Type
1	100	CA	Front End Assembly	24	125	DM+DN	(L&R) Front. Dr Window Regulator
2	101	CS	Front Spoiler	25	127		Front. Door Molding
3	102	CC	Header - Nose Panel	26	128	DK+DL	(L&R) Side View Mirror
4	103		Front Valance	27	129	DR	Door Handle
5	104	CG	Grille	28	130	DC+DD	Rear Door Shell
6	105	CB	Front Bumper	29	133		Rear Door Hinge
7	107	CN	Frt. Bumper Reinforcement	30	135	DO+DP	(L&R) Rear Door Window Regulator
8	108		Bumper Shock Absorb	31	137		Rear Door Molding
9	109	CQ	Radiator Support	32	145	CT	Front Bumper End Cap
10	110	CE+CF	(L&R) Fender	33	NA	RT	Rear Bumper End Cap
11	111		Front. Fender Extension	34	146		Box Liner
12	112	CP	Inner Fender	35	147		Truck Topper
13	113		Front Fender Molding	36	148	XV	Luggage Rack
14	114	LA+LB	(L&R) Headlamp Assembly	37	150	RC	Rear Clip
15	116		Parklamp Assembly	38	152	RF	Roof Assembly
16	117	CD	Hood	39	153		Sun Roof Panel
17	118		Hood Hinge	40	154	PE	Pick up Cab
18	119	JC	Cowl	41	155	PA	Pick up Box
19	120	DA+DB	(L&R) Front. Door Shell	42	160	RD+RE	(L&R) Quarter Panel Assembly
20	121		Hood Gas Strut	43	161		Rear Qtr Extension
21	122	XT+XU	(LH&RH) Running Board	44	165		Rear Qtr Molding
22	123		Cowl Vent Panel	45	166	LK+LL	(L&R) Tail Light Assembly
23	124		Front Door Hinge	46	167	LP	Backup Lamp Assembly

Part Types Sold				Part Types Sold			
Part Type Count	Hollander Part No.	Pinnacle Part No.	Part Type	Part Type Count	Hollander Part No.	Pinnacle Part No.	Part Type
47	168		Side Marker Light - Rear	72	203	IG	Front Seat Tracks
48	169	RH	Rear Spoiler	73	204	IW+IX	(L&R) Interior Trim Panel, Front
49	170	PB	Decklid/Tailgate	74	205	IY+IZ	(L&R) Interior Trim Panel, Rear
50	172		Hatchback/Tailgate Lift Cylinder	75	206	II	Head Rest
51	174	RQ	Trunk Lid Hinge	76	209		Dome Light
52	176	LN	Stop Lamp - High Mounted	77	210	IE	Seat Belt
53	177		Fuel Filler Door	78	211		Motorized Seat Belt
54	179		Fuel Filler Neck	79	213		Hood Release Cable
55	181		Latches and Locks	80	215	IB	Rear or Second Seat
56	182		Box Rails	81	219		Seal Beams
57	184	RQ	Tailgate Hinge	82	220	IC	Third Seat
58	186		Rocker Panel	83	222		Carpet Front
59	187		Tailgate Molding	84	223		Carpet Rear
60	189	RK	Rocker Panel Mldg	85	224		Headliner
61	190	RA	Rear Bumper	86	225		Misc., Trim Pad
62	191	RM	Rear Bumper Rebar	87	226		Window Crank, Front
63	192		Bumper Filler	88	227		Window Crank, Rear
64	194		Tail Center Panel	89	234		Accelerator Parts
65	195		Tail Panel Molding	90	235	JL	Steering Wheel
66	197	FK	Fuel Tank	91	237		Steering Shaft
67	198		Pillar	92	238	JD	Steering Column
68	199		Exterior Misc.	93	241	IM	Console Assembly
69	200	ID	Complete Interior	94	242	BH	Floor Shift Assembly
70	201	IA	Bench Seat	95	250	JI	Dash Assembly
71	202	IA	Bucket Seat	96	251		Dash Panel

Part Types Sold				Part Types Sold			
Part Type Count	Hollander Part No.	Pinnacle Part No.	Part Type	Part Type Count	Hollander Part No.	Pinnacle Part No.	Part Type
97	252		Dash Pad	122	309	AN	Harmonic Balancer
98	253	JA	L Air Bag Assembly	123	310		Belt Tensioner
99	253	JB	R Air Bag Assembly	124	311	AF	Oil Pan
100	254		Instrument Cluster Cover	125	317	NF	Intercooler
101	256		Clock	126	318		Engine Oil Cooler
102	257	JF	Speedometer	127	319	FA	Air Cleaner Assembly
103	258		Tachometer	128	320		Carburetor
104	260	IR	Glove Box	129	321	AH	Turbo-Super Charger
105	261		Clock Spring	130	321	AD	Turbo-Super Charger
106	265		Truck Seats	131	322	FC	Fuel Injection Parts
107	266	IO	Arm Rest	132	323	FL	Fuel Pump
108	267	JJ	Interior Mirror	133	324		Water Pump
109	268	IN	SunVisor	134	325		Fan Blade
110	270	GA	Windshield Glass	135	326	AG	Fan Clutch
111	275	GB	Back Glass	136	327	KA	Exhaust Manifold
112	277	GC+GD	(L&R) Front Door Glass	137	328	KE	Exhaust Assembly
113	278	GE+GF	(L&R) Rear Door Glass	138	329	FI	Intake Manifold
114	279	GP+GQ	(L&R) Rear Door Vent Glass	139	333	KC	Muffler
115	280	GM	Frt. Door Vent Glass Assembly	140	335	KD	Catalytic Converter
116	284	GG+GH	(L&R) Rear Quarter Glass	141	336	FB	Air Flow Meter
117	288	GI	Roof Glass/Sunroof/T	142	337	FD	Throttle Body
118	299		Interior Misc.	143	341	AQ	Air Injection Pump
119	300	AA	Engine Assembly	144	342	ME	Brackets Misc.
120	306	AB	Cylinder Head	145	343	AO	Engine Mounts
121	308		Timing Cover	146	350		Valve Cover

Part Types Sold				Part Types Sold			
Part Type Count	Hollander Part No.	Pinnacle Part No.	Part Type	Part Type Count	Hollander Part No.	Pinnacle Part No.	Part Type
147	370	FF	Fuel Injection Pump	172	445		Ring Gear - Pinion
148	372		Vacuum Pump	173	447	BC+BD	(L&R) Axle Shaft
149	375		Fuel Vapor Canister	174	475	UG	Rear Suspension Assembly
150	390		Flywheel Cover - SGI	175	476	QD	Rear Axle Beam
151	399		Engine Misc.	176	477		Suspension Cross Member
152	400	BA	Transmission - Transaxle	177	490	UM+UL	(L&R) Rear stub/Rear spindle
153	405		Auto Transmission Parts	178	499		Axle Parts Misc.
154	406		Pressure Plate	179	500	PC	Frame Assembly
155	408		Bell Housing	180	501		Half - Stub Frame
156	409	AE	Flywheel	181	505	UN	(R) Control Arm Upper Rear
157	410		Clutch Disc	182	507		Suspension. Trailing Arm
158	411		Transmission Adapter	183	510	TA+TB+ UA+UB	(L&R F/ L&R R) Knee Assembly
159	412	BB	Transfer Case Assembly	184	511	TK+TL	(L&R) Control Arm Upper Front
160	414		Transmission Oil Cooler	185	512	TE+TF	(L&R) Control Arm Lower Front
161	417		Clutch Master Cylinder	186	513	UF	(RR) Control Arm Lower Rear
162	418		Clutch Slave Cylinder	187	515	TH+TI	(L&R) Suspension Spindle Front
163	420	BM	Transfer Case Motor	188	516		Leaf Spring Front
164	422		Trans Cross member	189	517	TJ+UI	(F&R) Coil Spring
165	430	OB	Front Drive Shaft	190	518	PK	Leaf Spring Rear
166	431	OA	Rear Drive Shaft	191	519		Air Spring
167	434	QA	Front Axle Assembly	192	520		I Beam Front Axle
168	435	QB	Axle Assembly, Rear	193	521	TO	(Front) Torsion Bar
169	437		Axle Housing	194	522	UQ	Air Ride/Suspension Compressor
170	440	QC	Differential Carrier Assembly	195	523		Susp. Trunion Arm
171	441		Differential misc.	196	524	TN	Stabilizer Bar

Part Types Sold				Part Types Sold			
Part Type Count	Hollander Part No.	Pinnacle Part No.	Part Type	Part Type Count	Hollander Part No.	Pinnacle Part No.	Part Type
197	526		Shock Absorber	222	567		Wheel Lug Nut
198	527	TC+TD+ UC+UD	(L&R F/ L&R R) Strut	223	570	WB	Wheel Cover
199	530		Hub Drum - Rotor Front	224	575		Trim Ring
200	533		Drum - Rotor Rear	225	579		Wheel and Tire
201	534	WE	Brake Misc., Front	226	580		Center Cap
202	535		Brake Misc., Rear	227	585	WC	Tires
203	536	WN+WO	(L&R F) Caliper	228	586	PP	Trailer Hitch
204	537		Locking Hubs	229	590	EC	Electronic Module
205	538	UK	Hub	230	591	ED	Chassis Control Module
206	539		Brake Proportioning Valve	231	592		Electronic Misc.
207	540	WI	Power Brake Booster	232	593		Ignition Module
208	541	WG	Brake Master Cylinder	233	594	EQ	Info-GPS-TV Screen
209	543		Backing Plate Front	234	599		Suspension. Misc.
210	545	WH	ABS Brake Parts	235	600	XA	Battery
211	547		Emergency Brake Parts	236	601	EA	Alternator
212	548		Wheel Speed Sensor	237	604	EB	Starting Motor or Starter
213	549		Power steering Cooler	238	606	AC	Distributor
214	551	SA	Steering Gear	239	607	MK	Battery Tray
215	553	SB	Power Steering Pump	240	610	EJ	Coil/Coil Pack
216	555		Power Steering Pressure Hose	241	612	IH	Motor, Seat
217	558		Drive Link	242	613	EM	Horn
218	560	WA	Wheel	243	615	EE	Heater Blower Motor
219	564	WL	Jacks	244	617	DG+DJ	(LF Door/ RR Door) Power Window Motor
220	565		Inner Fender Liner	245	618	EI	Rear Window Wiper Motor
221	566	WK	Spare Wheel Carrier	246	619	CH+CI	(L&R) Concealed Head Light Activator

Part Types Sold				Part Types Sold			
Part Type Count	Hollander Part No.	Pinnacle Part No.	Part Type	Part Type Count	Hollander Part No.	Pinnacle Part No.	Part Type
247	620	EH	Windshield Wiper Motor	272	659		Seat, Dash, Console Switch
248	621	JM	Windshield Wiper Transmission	273	661		Amplifier
249	622		Windshield Washer Motor	274	671	NI	Radiator Overflow Bottle/Tank
250	624		Cruise Transducer	275	673	ND	Radiator Fan Shroud
251	626	JN	Wiper Arm	276	674	HC	Radiator Fan Motor
252	627	JO	Windshield Washer Tank	277	675	NA	Radiator
253	629	VA	Column Electrical Switch	278	676	HH	Heater Core
254	630	LE+LF	(L&R) Headlamp Door - Cover	279	677		Heater Assembly
255	633	VB	Ignition Switch	280	678		Heater Housing
256	637	FJ	Fuel Tank Sending Unit	281	679	HB	AC Condenser
257	638	EG	A/V Equipment	282	680	HF	AC Evaporator
258	640		Trunk Pull down	283	681	HG	AC Evaporator Housing
259	641		Electric Switch Panel	284	682	HA	AC Compressor
260	642		Electric Door Motor	285	683		AC Hoses
261	643		Door Lock Actuator	286	685		Heater - AC Parts
262	644		Radio Speaker	287	694		Owner's manual
263	645		Antenna	288	699		Electrical Misc.
264	646	EN	Fuse Box	289	875	MA	Surplus Misc.
265	647	EO	Lamp Wiring Harness	290	NA	HL	A/C Dryer
266	648	EO	Wiring Harness - Engine	291	NA	PD	Cab Clip
267	649	EO	Wiring Harness - Dash	292	NA	ZZ	Complete Vehicle
268	650	EO	Body Wiring Harness	293	NA	RN	Conv. Lift Motor
269	652		Circuit Board, Misc	294	NA	AJ	Crankshaft
270	653	JG	Air Bag Detector	295	NA	PF	Engine Crossmember
271	655		Temperature Control	296	NA	LM	Finish Panel - Rear

Part Types Sold			
Part Type Count	Hollander Part No.	Pinnacle Part No.	Part Type
297	NA	RP	Floor Pan
298	NA	HE	Heat/Ac Controler
299	NA	CK	Hood Latch
300	NA	LC+LD	(L&R) Front Lamp
301	NA	DE+DF	(L&R) Rocker & Post
302	NA	IV	Lid Trim Panel
303	NA	MD	Misc Pulley
304	NA	VI	Pwr Dr Wind Switch
305	NA	UP	Rear Sway Bar
306	NA	IS	Rear Trim
307	NA	BI	Transmission Mount

APPENDIX C Examples of the process flow diagrams for the participating dismantlers.

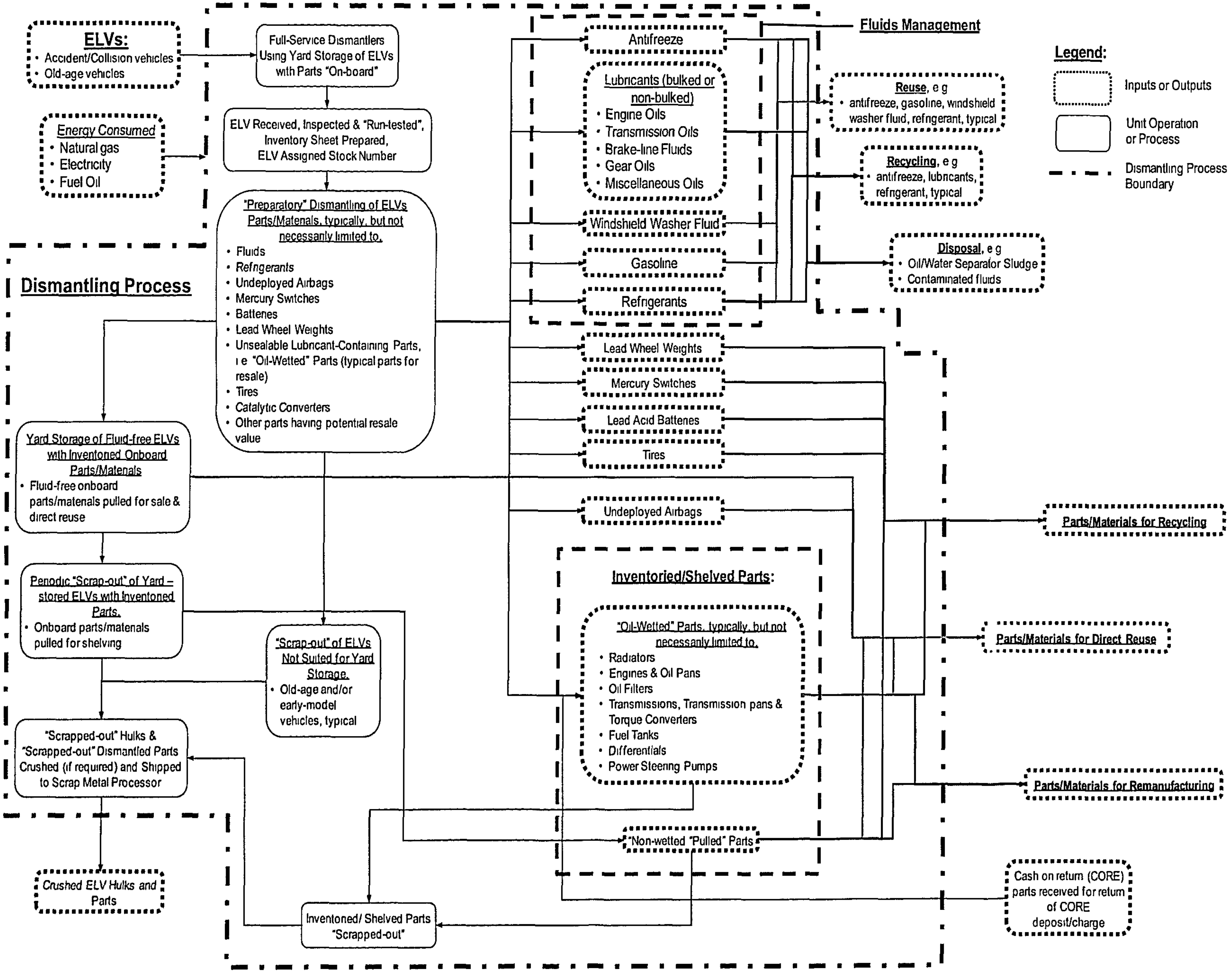

Figure 49 Example #1 of the process flow diagram for one of the full service dismantlers.

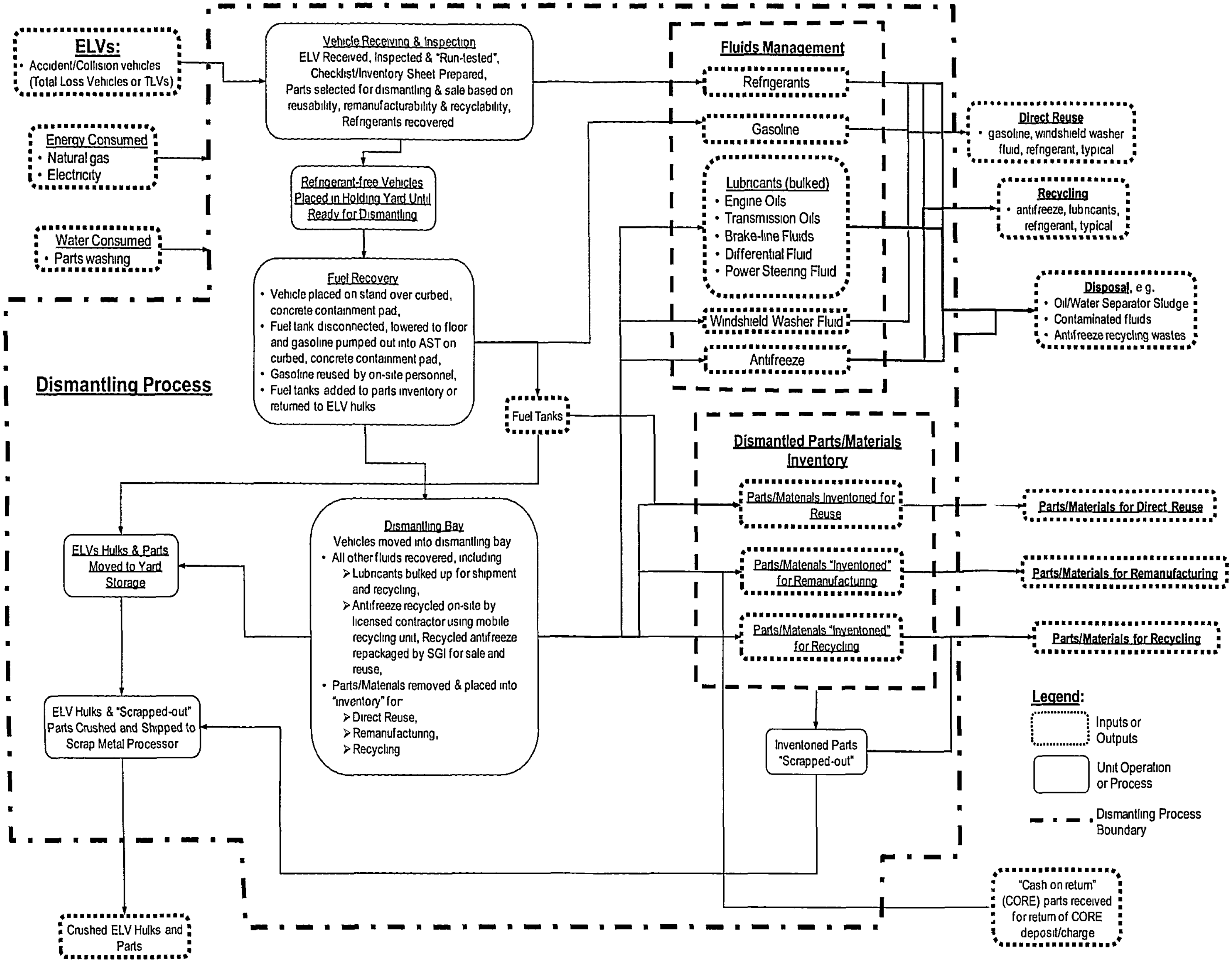

Figure 50 Example #2 of the process flow diagram for one of the full service dismantlers.

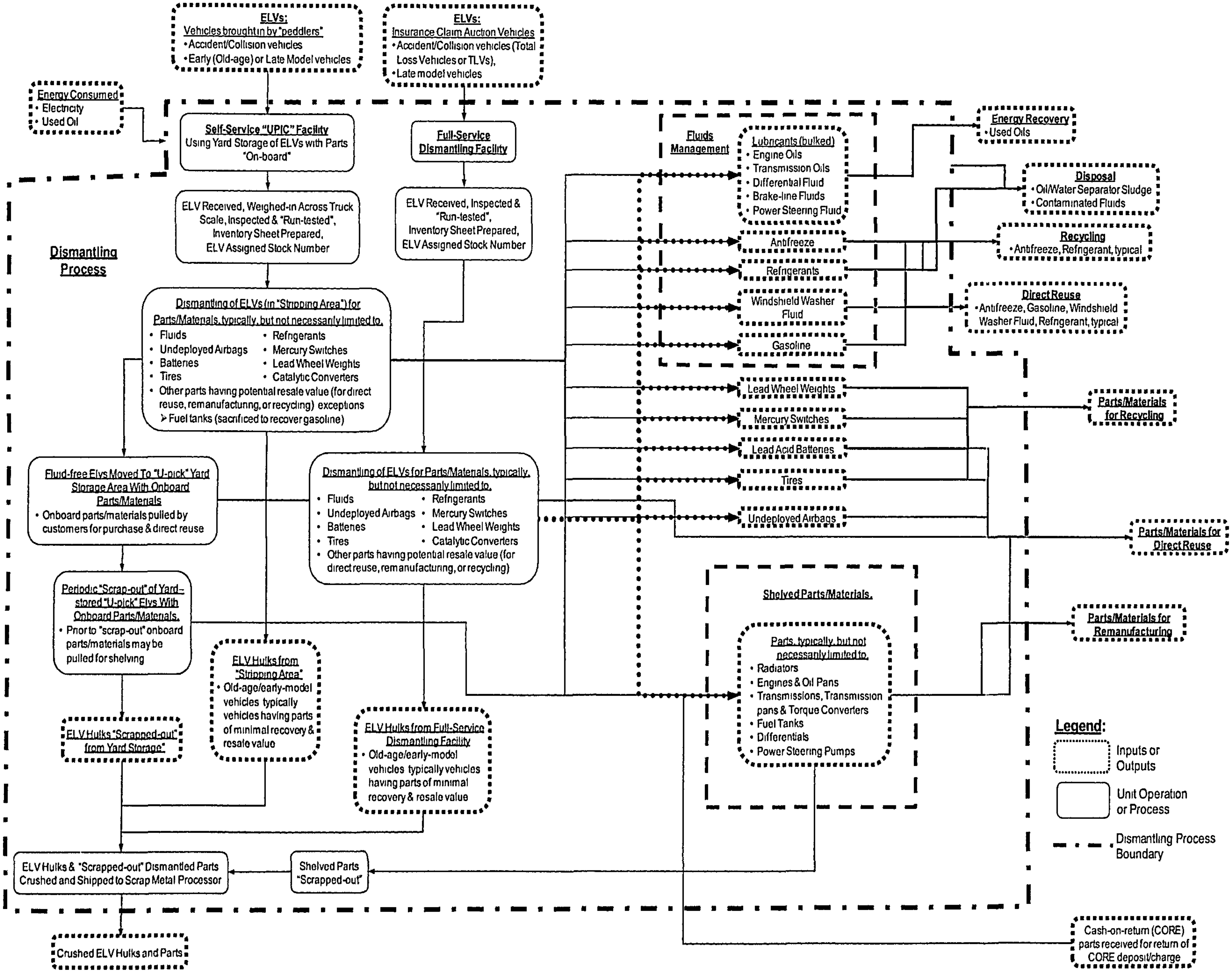

Figure 51 Example #3 of the process flow diagram for the dismantler having full-service & self-service facilities.

APPENDIX D Calculation Methodology

1) DISMANTLING PROCESS INPUTS:

a. HSELVs (high-salvage ELV)s:

i. *Mass of HSELVs received and processed in 2005, by Vehicle Make, Model and Model Year:*

$$\begin{aligned}&\mathit{Total\ Vehicle\ Mass\ (kg)\ of\ HSELV\ Make, w, Model, x, and\ Model\ Year, y, recieved\ and}\\&\mathit{processed\ in\ } 2005, TVM_{HSELVs,w,x,y}\\&= VehCt_{HSELVs,w,x,y}\left[\frac{\sum CbWt_{HSELVs,w,x,y,z}}{v}\right], \mathit{where:}\end{aligned}$$

$VehCt_{HSELVs,w,x,y} = \mathit{Vehicle\ Count\ of\ HSELV\ Make, w, Model, x, and\ Model\ Year, y,}$ $\mathit{received\ and\ processed\ in\ }2005$

$CbWt_{HSELVs,w,x,y,z} = \mathit{Curb\ Weight\ of\ HSELV\ Make, w, Model, x, Model\ Year, y, and}$ $\mathit{Body/Trim\ Style, z};$

$v = \mathit{Curb\ Weight\ count\ for\ HSELV\ Make, w, Model, x, Model\ Year, y, and\ Body/Trim\ Style, z.}$

ii. *Total Mass of HSELVs received and processed in 2005:*

$$\begin{aligned}&\mathit{Total\ Vehicle\ Mass\ (kg)\ of\ HSELVs, recieved\ and\ processed\ in\ }2005, TVM_{HSELVs:}\\&= \sum TVM_{HSELVs,w,x,y}\end{aligned}$$

iii. *HSELVs processed, per tonne of ELVs received and processed in 2005:*

$$\frac{kg\ HSELVs}{tonne\ ELVs\ Retired} = \frac{Tonnes\ HSELVs\ Processed\ in\ 2005}{kg\ HSELVs + LSELVs\ Received\ and\ Processed\ in\ 2005} \times \frac{1000\ kg}{tonne}$$

$$= 132.4\ \ kg/tonne\ ELVs\ Recieved\ and\ Processed$$

b. LSELVs (low-salvage ELVs):

i. *Mass of LSELVs received and processed in 2005, by Vehicle Make, Model and Model Year:*

$$\begin{aligned}&\mathit{Total\ Vehicle\ Mass\ (kg)\ of\ LSELV\ Make, w, Model, x, and\ Model\ Year, y, recieved\ and}\\&\mathit{processed\ in\ } 2005, TVM_{LSELVs,w,x,y}\\&= VehCt_{LSELVs,w,x,y}\left[\frac{\sum CbWt_{LSELVs,w,x,y,z}}{v}\right], \mathit{where:}\end{aligned}$$

$VehCt_{LSELVs,w,x,y} = \mathit{Vehicle\ Count\ of\ LSELV\ Make, w, Model, x\ and\ Model\ Year, y,}$ $\mathit{received\ and\ processed\ in\ }2005$

$CbWt_{LSELVs,w,x,y,z} = \mathit{Curb\ Weight\ of\ LSELV\ Make, w, Model, x, Model\ Year, y, and}$ $\mathit{Body/Trim\ Style, z};$

$v = \mathit{Curb\ Weight\ count\ for\ LSELV\ Make, w, Model, x, Model\ Year, y, and\ Body/Trim\ Style, z}$

ii. *Total Mass of LSELVs received and processed in 2005:*

$Total\ Vehicle\ Mass\ (kg)\ of\ LSELVs, recieved\ and\ processed\ in\ 2005, TVM_{LSELVs}$:

$$= \sum TVM_{LSELVs,w,x,y}$$

iii. *LSELVs processed, per tonne of ELVs received and processed in 2005:*

$$\frac{kg\ LSELVs}{tonne\ ELVs\ Retired} = \frac{Tonnes\ LSELVs\ Processed\ in\ 2005}{kg\ HSELVs + LSELVs\ Received\ and\ Processed\ in\ 2005} \times \frac{1000\ kg}{tonne}$$

$$= 867.6\ kg/tonne\ ELVs\ Recieved\ and\ Processed$$

c. CORE Parts Received:

i. *Mass of CORE parts, by Part Type:*

$\boldsymbol{a. If\ for\ CORE\ Part\ Type, i, PtCt_{i,CORES} \geq 3, PtWt_{i,Neon} > 0, PtWt_{i,Voyager} > 0,}$
$\boldsymbol{PtWt_{i,Explorer} > 0\ and\ PtWt_{i,Misc} \geq 0, then\ Total\ Parts\ Mass\ (kg)\ for}$
$\boldsymbol{Part\ Type, i, recieved\ as\ CORE\ parts, TPM_{i,COREs} =}$

$$PtCt_{i,COREs}\left[PtWt_{i,Neon}(\%VVeh_{HSELVs,T} + \%VVeh_{HSELVs,S} + \%VVeh_{HSELVs,C} + \%VVeh_{HSELVs,M}) + PtWt_{i,Voyager}(\%VVeh_{HSELVs,L} + \%VVeh_{HSELVs,W} + \%VVeh_{HSELVs,V}) + PtWt_{i,Explorer}(\%VVeh_{HSELVs,SP} + \%VVeh_{HSELVs,P})\right] \div 100, where:$$

$PtCt_{i,COREs} = Part\ Count\ for\ Part\ Type, i, recieved\ as\ CORE\ parts;$

$PtWt_{i,Neon} = Part\ Weight\ (kg) for\ Part\ Type, i, from\ 1997\ Neon;$

$PtWt_{i,Voyager} = Part\ Weight\ (kg) for\ Part\ Type, i, from\ 1996\ Voyager;$

$PtWt_{i,Explorer} = Part\ Weight\ (kg) for\ Part\ Type, i, from\ 1994\ Explorer$

$PtWt_{i,Misc} = Part\ Weight\ (kg) for\ Part\ Type, i, from\ Miscellaneous\ Part\ Mass\ Study\ Vehicle$

$\%VVeh_{HSELVs,T} = \%\ Unit\ Volume\ HSELVs\ in\ Two\ seater(T)\ Vehicle\ Size\ Class;$

$\%VVeh_{HSELVs,S} = \%\ Unit\ Volume\ HSELVs\ in\ Subcompact(S)\ Vehicle\ Size\ Class;$

$\%VVeh_{HSELVs,C} = \%\ Unit\ Volume\ HSELVs\ in\ Compact(C)\ Vehicle\ Size\ Class;$

$\%VVeh_{HSELVs,M} = \%\ Unit\ Volume\ HSELVs\ in\ Midsize(M)\ Vehicle\ Size\ Class;$

$\%VVeh_{HSELVs,L} = \%\ Unit\ Volume\ HSELVs\ in\ Largesize(L)\ Vehicle\ Size\ Class;$

$\%VVeh_{HSELVs,W} = \%\ Unit\ Volume\ HSELVs\ in\ Station\ Wagon(W)\ Vehicle\ Size\ Class;$

$\%VVeh_{HSELVs,SP} = \%\ Unit\ Volume\ HSELVs\ in\ Special\ Purpose(SP)\ Vehicle\ Size\ Class;$

$\%VVeh_{HSELVs,P} = \%\ Unit\ Volume\ HSELVs\ in\ Pickup(P)\ Vehicle\ Size\ Class.$

$\boldsymbol{b. If\ for\ CORE\ Part\ Type, i, PtCt_{i,CORES} < 3, PtWt_{i,Neon} > 0, PtWt_{i,Voyager} > 0,}$
$\boldsymbol{PtWt_{i,Explorer} > 0\ and\ PtWt_{i,Misc} \geq 0, then\ Total\ Parts\ Mass\ (kg)\ for}$
$\boldsymbol{Part\ Type, i, recieved\ as\ CORE\ parts, TPM_{i,COREs} =}$

$$PtCt_{i,COREs}\left[\frac{PtWt_{i,Neon} + PtWt_{i,Voyager} + PtWt_{i,Explorer}}{3}\right]$$

c. If for CORE Part Type, i, $PtCt_{i,CORES} \geq 3$, $PtWt_{i,Neon} = 0$, $PtWt_{i,Voyager} > 0$, $PtWt_{i,Explorer} > 0$ and $PtWt_{i,Misc} = 0$, then Total Parts Mass (kg) for Part Type, i, recieved as CORE parts, $TPM_{i,COREs} =$

$$PtCt_{i,COREs}\left[PtWt_{i,Voyager}(\%VVeh_{HSELVs,T} + \%VVeh_{HSELVs,S} + \%VVeh_{HSELVs,C} + \%VVeh_{HSELVs,M} + \%VVeh_{HSELVs,L} + \%VVeh_{HSELVs,W} + \%VVeh_{HSELVs,V}) + PtWt_{i,Explorer}(\%VVeh_{HSELVs,SP} + \%VVeh_{HSELVs,P})\right] \div 100$$

d. If for CORE Part Type, i, $PtCt_{i,CORES} < 3$, $PtWt_{i,Neon} = 0$, $PtWt_{i,Voyager} > 0$, $PtWt_{i,Explorer} > 0$ and $PtWt_{i,Misc} = 0$, then Total Parts Mass (kg) for Part Type, i, recieved as CORE parts, $TPM_{i,COREs} =$

$$PtCt_{i,COREs}\left[\frac{PtWt_{i,Voyager} + PtWt_{i,Explorer}}{2}\right]$$

e. If for CORE Part Type, i, $PtCt_{i,CORES} \geq 3$, $PtWt_{i,Neon} > 0$, $PtWt_{i,Voyager} > 0$, $PtWt_{i,Explorer} = 0$ and $PtWt_{i,Misc} = 0$, then Total Parts Mass (kg) for Part Type, i, recieved as CORE parts, $TPM_{i,COREs} =$

$$PtCt_{i,COREs}\left[PtWt_{i,Neon}(\%VVeh_{HSELVs,T} + \%VVeh_{HSELVs,S} + \%VVeh_{HSELVs,C} + \%VVeh_{HSELVs,M}) + PtWt_{i,Voyager}(\%VVeh_{HSELVs,L} + \%VVeh_{HSELVs,W} + \%VVeh_{HSELVs,V} + \%VVeh_{HSELVs,SP} + \%VVeh_{HSELVs,P})\right] \div 100$$

f. If for CORE Part Type, i, $PtCt_{i,CORES} < 3$, $PtWt_{i,Neon} > 0$, $PtWt_{i,Voyager} > 0$, $PtWt_{i,Explorer} = 0$ and $PtWt_{i,Misc} = 0$, then Total Parts Mass (kg) for Part Type, i, recieved as CORE parts, $TPM_{i,COREs} =$

$$PtCt_{i,COREs}\left[\frac{PtWt_{i,Neon} + PtWt_{i,Voyager}}{2}\right]$$

g. If for CORE Part Type, i, $PtCt_{i,CORES} \geq 3$, $PtWt_{i,Neon} > 0$, $PtWt_{i,Voyager} = 0$, $PtWt_{i,Explorer} > 0$ and $PtWt_{i,Misc} = 0$, then Total Parts Mass (kg) for Part Type, i, recieved as CORE parts, $TPM_{i,COREs} =$

$$PtCt_{i,COREs}\left[PtWt_{i,Neon}(\%VVeh_{HSELVs,T} + \%VVeh_{HSELVs,S} + \%VVeh_{HSELVs,C} + \%VVeh_{HSELVs,M}) + PtWt_{i,Explorer}(\%VVeh_{HSELVs,L} + \%VVeh_{HSELVs,W} + \%VVeh_{HSELVs,V} + \%VVeh_{HSELVs,SP} + \%VVeh_{HSELVs,P})\right] \div 100$$

h. If for CORE Part Type, i, $PtCt_{i,CORES} < 3$, $PtWt_{i,Neon} > 0$, $PtWt_{i,Voyager} = 0$, $PtWt_{i,Explorer} > 0$ and $PtWt_{i,Misc} = 0$, then Total Parts Mass (kg) for Part Type, i, recieved as CORE parts, $TPM_{i,COREs} =$

$$PtCt_{i,COREs}\left[\frac{PtWt_{i,Neon}+PtWt_{i,Explorer}}{2}\right]$$

$$\boldsymbol{i.\,If\ for\ CORE\ Part\ Type, i, PtWt_{i,Neon}} > 0\ or\ \boldsymbol{PtWt_{i,Voyager}} > 0\ or\ \boldsymbol{PtWt_{i,Explorer}} > 0\ \boldsymbol{and\ PtWt_{i,Misc}} > 0, then\ Total\ Parts\ Mass\ \boldsymbol{(kg)\ for\ Part\ Type, i, recieved\ as\ CORE\ parts, TPM_{i,COREs}} =$$

$$PtCt_{i,COREs}\left[PtWt_{i,m}+PtWt_{i,Misc}\right] \div 2, where:$$

$$PtWt_{i,m} = Part\ Weight\ (kg) for\ Part\ Type, i, from\ Part\ Mass\ Study\ Vehicle, m, where\ m = Neon\ or\ Voyager\ or\ Explorer$$

$$\boldsymbol{j.\,If\ for\ CORE\ Part\ Type, i, PtWt_{i,Neon}} > 0\ and\ \boldsymbol{PtWt_{i,Voyager}} > 0, or\ \boldsymbol{PtWt_{i,Neon}} > 0\ and\ \boldsymbol{PtWt_{i,Explorer}} > 0, or\ \boldsymbol{PtWt_{i,Voyager}} > 0\ and\ \boldsymbol{PtWt_{i,Explorer}} > 0, \boldsymbol{and\ PtWt_{i,Misc}} > 0, then\ Total\ Parts\ Mass\ \boldsymbol{(kg)\ for\ Part\ Type, i, recieved\ as\ CORE\ parts, TPM_{i,COREs}} =$$

$$PtCt_{i,COREs}\left[\sum PtWt_{i,m}+PtWt_{i,Misc}\right] \div 3, where:$$

$$PtWt_{i,m} = Part\ Weight\ (kg) for\ Part\ Type, i, from\ Part\ Mass\ Study\ Vehicle, m, where\ m = Neon\ and\ Voyager, or\ Neon\ and\ Explorer, or\ Voyager\ and\ Explore$$

$$\boldsymbol{k.\,If\ for\ CORE\ Part\ Type, i, PtWt_{i,Neon}} > 0\ or\ \boldsymbol{PtWt_{i,Voyager}} > 0\ or\ \boldsymbol{PtWt_{i,Explorer}} > 0\ \boldsymbol{or\ PtWt_{i,Misc}} > 0, then\ Total\ Parts\ Mass\ \boldsymbol{(kg)\ for\ Part\ Type, i, recieved\ as\ CORE\ parts, TPM_{i,COREs}} =$$

$$PtCt_{i,COREs} \times PtWt_{i,m}, where:$$

$$PtWt_{i,m} = Part\ Weight\ (kg) for\ Part\ Type, i, from\ Part\ Mass\ Study\ Vehicle, m, where\ m = Neon, Voyager, Explorer\ or\ Miscellaneous\ Part\ Vehicle$$

ii. <u>CORE parts, by Part Type, per tonne HSELV Parts Sold for Reuse:</u>

$$\frac{kg\ CORE\ Part\ Type, i}{tonne\ HSELVs\ Parts\ Sold\ for\ Reuse} = \frac{TPM_{i,COREs}}{kg\ HSELVs\ Parts\ Sold\ for\ Reuse\ in\ 2005} \times \frac{1000\ kg}{tonne}$$

iii. <u>CORE parts, by Part Type, per tonne ELVs and CORE Parts Processed:</u>

$$\frac{kg\ CORE\ Part\ Type, i}{tonne\ ELVs\ \&\ CORE\ Parts\ Processed} = \frac{TPM_{i,COREs}}{kg\ HSELVs + LSELVs + CORE\ Parts\ Processed\ in\ 2005} \times \frac{1000\ kg}{tonne}$$

a. Electrical Energy:

$$\frac{kW\text{-}hr\ Electrical\ Energy}{tonne\ ELVs\ processed} = \frac{kW\text{-}hr\ Elect\ in\ 2005}{kg\ HSELVs + LSELVs\ Received\ and\ Processed\ in\ 2005} \times \frac{1000\ kg}{tonne}$$

$$= 23.1\ kW\text{-}hr/tonne\ ELVs\ processed$$

2) DISMANTLING PROCESS OUTPUTS:

a. HSELV Parts Directed For Reuse:

i. *Mass of Reusable HSELV parts, by Part Type:*

$$\boldsymbol{a.\ If\ for\ HSELV\ Part\ Type, i, PtCt_{i,HSELVs,Reuse} \geq 3, PtWt_{i,Neon} > 0, PtWt_{i,Voyager} > 0,}$$
$$\boldsymbol{PtWt_{i,Explorer} > 0\ and\ PtWt_{i,Misc} \geq 0, then\ Total\ Parts\ Mass\ (kg)\ for}$$
$$\boldsymbol{Part\ Type, i, from\ HSELVs\ sold\ for\ Reuse, TPM_{i,HSELVs,Reuse} =}$$

$$PtCt_{i,HSELVs,Reuse}\big[PtWt_{i,Neon}\big(\%VVeh_{HSELVs,T} + \%VVeh_{HSELVs,S} + \%VVeh_{HSELVs,C} + \%VVeh_{HSELVs,M}\big) + PtWt_{i,Voyager}\big(\%VVeh_{HSELVs,L} + \%VVeh_{HSELVs,W} + \%VVeh_{HSELVs,V}\big) + PtWt_{i,Explorer}\big(\%VVeh_{HSELVs,SP} + \%VVeh_{HSELVs,P}\big)\big] \div 100, where:$$

$PtCt_{i,HSELVs,Reuse} = Part\ Count\ for\ Part\ Type, i, from\ HSELVs\ sold\ for\ Reuse;$

$PtWt_{i,Neon} = Part\ Weight\ (kg) for\ Part\ Type, i, from\ 1997\ Neon;$

$PtWt_{i,Voyager} = Part\ Weight\ (kg) for\ Part\ Type, i, from\ 1996\ Voyager;$

$PtWt_{i,Explorer} = Part\ Weight\ (kg) for\ Part\ Type, i, from\ 1994\ Explorer$

$PtWt_{i,Misc} = Part\ Weight\ (kg) for\ Part\ Type, i, from\ Miscellaneous\ Part\ Mass\ Study\ Vehicle$

$\%VVeh_{HSELVs,T} = \%\ Unit\ Volume\ HSELVs\ in\ Two\ seater(T)\ Vehicle\ Size\ Class;$

$\%VVeh_{HSELVs,S} = \%\ Unit\ Volume\ HSELVs\ in\ Subcompact(S)\ Vehicle\ Size\ Class;$

$\%VVeh_{HSELVs,C} = \%\ Unit\ Volume\ HSELVs\ in\ Compact(C)\ Vehicle\ Size\ Class;$

$\%VVeh_{HSELVs,M} = \%\ Unit\ Volume\ HSELVs\ in\ Midsize(M)\ Vehicle\ Size\ Class;$

$\%VVeh_{HSELVs,L} = \%\ Unit\ Volume\ HSELVs\ in\ Largesize(L)\ Vehicle\ Size\ Class;$

$\%VVeh_{HSELVs,W} = \%\ Unit\ Volume\ HSELVs\ in\ Station\ Wagon(W)\ Vehicle\ Size\ Class;$

$\%VVeh_{HSELVs,SP} = \%\ Unit\ Volume\ HSELVs\ in\ Special\ Purpose(SP)\ Vehicle\ Size\ Class;$

$\%VVeh_{HSELVs,P} = \%\ Unit\ Volume\ HSELVs\ in\ Pickup(P)\ Vehicle\ Size\ Class.$

$$\boldsymbol{b.\ If\ for\ HSELV\ Part\ Type, i, PtCt_{i,HSELVs,Reuse} < 3, PtWt_{i,Neon} > 0, PtWt_{i,Voyager} > 0,}$$
$$\boldsymbol{PtWt_{i,Explorer} > 0\ and\ PtWt_{i,Misc} \geq 0, then\ Total\ Parts\ Mass\ (kg)\ for}$$
$$\boldsymbol{Part\ Type, i, from\ HSELVs\ sold\ for\ Reuse, TPM_{i,HSELVs,Reuse} =}$$

$$PtCt_{i,HSELVs,Reuse}\left[\frac{PtWt_{i,Neon} + PtWt_{i,Voyager} + PtWt_{i,Explorer}}{3}\right]$$

$$\boldsymbol{c.\ If\ for\ HSELV\ Part\ Type, i, PtCt_{i,HSELVs,Reuse} \geq 3, PtWt_{i,Neon} = 0, PtWt_{i,Voyager} > 0,}$$
$$\boldsymbol{PtWt_{i,Explorer} > 0\ and\ PtWt_{i,Misc} = 0, then\ Total\ Parts\ Mass\ (kg)\ for\ Part\ Type, i,}$$
$$\boldsymbol{from\ HSELVs\ sold\ for\ Reuse, TPM_{i,HSELVs,Reuse} =}$$

$$\begin{aligned}&PtCt_{i,HSELVs,Reuse}\Big[PtWt_{i,Voyager}\big(\%VVeh_{HSELVs,T} + \%VVeh_{HSELVs,S} + \%VVeh_{HSELVs,C}\\&\quad + \%VVeh_{HSELVs,M} + \%VVeh_{HSELVs,L} + \%VVeh_{HSELVs,W} + \%VVeh_{HSELVs,V}\big)\\&\quad + PtWt_{i,Explorer}\big(\%VVeh_{HSELVs,SP} + \%VVeh_{HSELVs,P}\big)\Big] \div 100\end{aligned}$$

d. If for HSELV Part Type, i, $\boldsymbol{PtCt_{i,HSELVs,Reuse}} < 3, \boldsymbol{PtWt_{i,Neon} = 0, PtWt_{i,Voyager}} > 0, \boldsymbol{PtWt_{i,Explorer}} > 0$ *and* $\boldsymbol{PtWt_{i,Misc} = 0}$***, then Total Parts Mass (kg) for Part Type, i, from HSELVs sold for Reuse,*** $\boldsymbol{TPM_{i,HSELVs,Reuse}} =$

$$PtCt_{i,HSELVs,Reuse}\left[\frac{PtWt_{i,Voyager} + PtWt_{i,Explorer}}{2}\right]$$

e. If for HSELV Part Type, i, $\boldsymbol{PtCt_{i,HSELVs,Reuse} \geq 3, PtWt_{i,Neon}} > 0, \boldsymbol{PtWt_{i,Voyager}} > 0, \boldsymbol{PtWt_{i,Explorer} = 0}$ ***and*** $\boldsymbol{PtWt_{i,Misc} = 0}$***, then Total Parts Mass (kg) for Part Type, i, from HSELVs sold for Reuse,*** $\boldsymbol{TPM_{i,HSELVs,Reuse}} =$

$$\begin{aligned}&PtCt_{i,HSELVs,Reuse}\Big[PtWt_{i,Neon}\big(\%VVeh_{HSELVs,T} + \%VVeh_{HSELVs,S} + \%VVeh_{HSELVs,C}\\&\quad + \%VVeh_{HSELVs,M}\big)\\&\quad + PtWt_{i,Voyager}\big(\%VVeh_{HSELVs,L} + \%VVeh_{HSELVs,W} + \%VVeh_{HSELVs,V} + \%VVeh_{HSELVs,SP}\\&\quad + \%VVeh_{HSELVs,P}\big)\Big] \div 100\end{aligned}$$

f. If for HSELV Part Type, i, $\boldsymbol{PtCt_{i,HSELVs,Reuse}} < 3, \boldsymbol{PtWt_{i,Neon}} > 0, \boldsymbol{PtWt_{i,Voyager}} > 0, \boldsymbol{PtWt_{i,Explorer}} = 0$ ***and*** $\boldsymbol{PtWt_{i,Misc} = 0}$***, then Total Parts Mass (kg) for Part Type, i, from HSELVs sold for Reuse,*** $\boldsymbol{TPM_{i,HSELVs,Reuse}} =$

$$PtCt_{i,HSELVs,Reuse}\left[\frac{PtWt_{i,Neon} + PtWt_{i,Voyager}}{2}\right]$$

g. If for HSELV Part Type, i, $\boldsymbol{PtCt_{i,HSELVs,Reuse} \geq 3, PtWt_{i,Neon}} > 0, \boldsymbol{PtWt_{i,Voyager} = 0, PtWt_{i,Explorer}} > 0$ *and* $\boldsymbol{PtWt_{i,Misc} = 0}$***, then Total Parts Mass (kg) for Part Type, i, from HSELVs sold for Reuse,*** $\boldsymbol{TPM_{i,HSELVs,Reuse}} =$

$$\begin{aligned}&PtCt_{i,HSELVs,Reuse}\Big[PtWt_{i,Neon}\big(\%VVeh_{HSELVs,T} + \%VVeh_{HSELVs,S} + \%VVeh_{HSELVs,C}\\&\quad + \%VVeh_{HSELVs,M}\big)\\&\quad + PtWt_{i,Explorer}\big(\%VVeh_{HSELVs,L} + \%VVeh_{HSELVs,W} + \%VVeh_{HSELVs,V} + \%VVeh_{HSELVs,SP}\\&\quad + \%VVeh_{HSELVs,P}\big)\Big] \div 100\end{aligned}$$

h. If for HSELV Part Type, i, $\boldsymbol{PtCt_{i,HSELVs,Reuse}} < 3, \boldsymbol{PtWt_{i,Neon}} > 0, \boldsymbol{PtWt_{i,Voyager} = 0}, \boldsymbol{PtWt_{i,Explorer}} > 0$ ***and*** $\boldsymbol{PtWt_{i,Misc} = 0}$***, then Total Parts Mass (kg) for Part Type, i, from HSELVs sold for Reuse,*** $\boldsymbol{TPM_{i,HSELVs,Reuse}} =$

$$PtCt_{i,HSELVs,Reuse}\left[\frac{PtWt_{i,Neon} + PtWt_{i,Explorer}}{2}\right]$$

i. If for HSELV Part Type, i, $PtWt_{i,Neon} > 0$ **or** $PtWt_{i,Voyager} > 0$ **or** $PtWt_{i,Explorer} > 0$**, and** $PtWt_{i,Misc} > 0$**, then Total Parts Mass (kg) for Part Type, i, from HSELVs sold for Reuse,** $TPM_{i,HSELVs,Reuse} =$

$$PtCt_{i,HSELVs,Reuse}\left[PtWt_{i,m} + PtWt_{i,Misc}\right] \div 2, \text{where:}$$

$PtWt_{i,m}$ = *Part Weight (kg) for Part Type, i, from Part Mass Study Vehicle, m, where m = Neon or Voyager or Explorer*

j. If for HSELV Part Type, i, $PtWt_{i,Neon} > 0$ **and** $PtWt_{i,Voyager} > 0$**, or** $PtWt_{i,Neon} > 0$ **and** $PtWt_{i,Explorer} > 0$**, or** $PtWt_{i,Voyager} > 0$ **and** $PtWt_{i,Explorer} > 0$**, and** $PtWt_{i,Misc} > 0$**, then Total Parts Mass (kg) for Part Type, i, from HSELVs sold for Reuse,** $TPM_{i,HSELVs,Reuse} =$

$$PtCt_{i,HSELVs,Reuse}\left[\sum PtWt_{i,m} + PtWt_{i,Misc}\right] \div 3, \text{where:}$$

$PtWt_{i,m}$ = *Part Weight (kg) for Part Type, i, from Part Mass Study Vehicle, m, where m = Neon and Voyager, or Neon and Explorer, or Voyager and Explore*

k. If for HSELV Part Type, i, $PtWt_{i,Neon} > 0$ **or** $PtWt_{i,Voyager} > 0$ **or** $PtWt_{i,Explorer} > 0$ **or** $PtWt_{i,Misc} > 0$**, then Total Parts Mass (kg) for Part Type, i, from HSELVs sold for Reuse,** $TPM_{i,HSELVs,Reuse} =$

$$PtCt_{i,HSELVs,Reuse} \times PtWt_{i,m}, \text{where:}$$

$PtWt_{i,m}$ = *Part Weight (kg) for Part Type, i, from Part Mass Study Vehicle, m, where m = Neon or Voyager or Explorer or Miscellaneous Part Vehicle*

ii. <u>Reusable HSELV parts, by Part Type, per tonne HSELVs Processed:</u>

$$\frac{\text{kg HSELV Part Type, i, Sold for Reuse}}{\text{tonne HSELVs Processed}} =$$

$$\frac{TPM_{i,HSELVs,Reuse}}{\text{kg HSELVs Processed in 2005}} \times \frac{1000\ kg}{tonne}$$

iii. <u>Reusable HSELV parts, by Part Type, per tonne ELVs Processed:</u>

$$\frac{\text{kg HSELV Part Type, i, Sold for Reuse}}{\text{tonne ELVs Processed}} =$$

$$\frac{TPM_{i,HSELVs,Reuse}}{\text{kg HSELVs + LSELVs Processed in 2005}} \times \frac{1000\ kg}{tonne}$$

iv. <u>Reusable HSELV parts, by Part Type, per tonne ELVs and CORE Parts Processed:</u>

$$\frac{\text{kg HSELV Part Type, i, Sold for Reuse}}{\text{tonne ELVs \& CORE Parts Processed}} =$$

$$\frac{TPM_{i,HSELVs,Reuse}}{kg\ HSELVs + LSELVs + CORE\ Parts\ Processed\ in\ 2005} \times \frac{1000\ kg}{tonne}$$

b. LSELV Parts Directed For Reuse:

i. *Mass of Reusable LSELV parts, by Part Type:*

$Total\ Parts\ Mass\ (kg) for\ Part\ Type, i, from\ LSELVs\ sold\ for\ Reuse\ annually, TPM_{i,LSELV,Reuse}$

$=$

$$PtCt_{i,LSELV,Reuse} \left[\frac{\sum PtWt_{i,m}}{c}\right] \times 2, where:$$

$PtCt_{i,LSELV,Reuse} = 6\text{-}months\ Part\ Count\ for\ Part\ Type, i, from\ LSELVs\ sold\ for\ Reuse;$

$PtWt_{i,m} = Part\ Weight\ (kg) for\ Part\ Type, i, from\ Vehicle, m, where\ m =$

$a\ vehicle\ from\ the\ Parts\ Mass\ Study\ (Neon, Voyager, Explorer\ or\ Miscellaneous\ Part\ Vehicle), or$

$USCAR\ VRP\ disassembled\ vehicle\ database, or\ the\ WWW;$

$c = Part\ Weight\ count$

ii. *Reusable LSELV parts, by Part Type, per tonne LSELVs Processed:*

$$\frac{kg\ LSELV\ Part\ Type, i, Sold\ for\ Reuse}{tonne\ LSELVs\ Processed} =$$

$$\frac{TPM_{i,LSELVs,Reuse}}{kg\ LSELVs\ Processed\ in\ 2005} \times \frac{1000\ kg}{tonne}$$

iii. *Reusable LSELV parts, by Part Type, per tonne ELVs Processed:*

$$\frac{kg\ LSELV\ Part\ Type, i, Sold\ for\ Reuse}{tonne\ ELVs\ Processed} =$$

$$\frac{TPM_{i,HSELVs,Reuse}}{kg\ HSELVs + LSELVs\ Processed\ in\ 2005} \times \frac{1000\ kg}{tonne}$$

iv. *Reusable LSELV parts, by Part Type, per tonne ELVs and CORE Parts Processed:*

$$\frac{kg\ LSELV\ Part\ Type, i, Sold\ for\ Reuse}{tonne\ ELVs\ \&\ CORE\ Parts\ Processed} =$$

$$\frac{TPM_{i,HSELVs,Reuse}}{kg\ HSELVs + LSELVs + CORE\ Parts\ Processed\ in\ 2005} \times \frac{1000\ kg}{tonne}$$

c. CORE Parts Directed For Reuse:

i. *Mass of Reusable CORE parts, by Part Type:*

$Total\ Parts\ Mass\ (kg) for\ CORE\ Part\ Type, i, received\ as\ CORE\ parts\ and\ sold\ for\ Reuse,$

$TPM_{i,CORE,Reuse} =$

$PtCt_{i,CORE,Reuse}\left[\frac{\sum PtWt_{i,m}}{c}\right], where:$

$PtCt_{i,CORE,Reuse} = Part\ Count\ for\ Part\ Type, i, received\ as\ CORE\ parts\ and\ sold\ for\ Reuse;$

$PtWt_{i,m} = Part\ Weight\ (kg) for\ Part\ Type, i, from\ Vehicle, m, where\ m$

$= Neon, Voyager, Explorer\ or\ Miscellaneous\ Part\ Vehicle$

$c = Part\ Weight\ count$

ii. *Reusable CORE parts, by Part Type, per tonne CORE Parts Received:*

$$\frac{kg\ LSELV\ Part\ Type, i, Sold\ for\ Reuse}{tonne\ LSELVs\ Processed} =$$

$$\frac{TPM_{i,CORE,Reuse}}{kg\ CORE\ Parts\ Received\ in\ 2005} \times \frac{1000\ kg}{tonne}$$

iii. *Reusable CORE parts, by Part Type, per tonne ELVs and CORE Parts Processed:*

$$\frac{kg\ CORE\ Part\ Type, i, Sold\ for\ Reuse}{tonne\ ELVs\ \&\ CORE\ Parts\ Processed} =$$

$$\frac{TPM_{i,CORE,Reuse}}{kg\ HSELVs + LSELVs + CORE\ Parts\ Processed\ in\ 2005} \times \frac{1000\ kg}{tonne}$$

d. HSELV Parts Directed For Remanufacturing:

i. *Mass of Remanufacturable HSELV parts, by Part Type:*

$Total\ Parts\ Mass\ (kg) for\ Part\ Type, i, from\ HSELVs\ bound\ for\ Remanufacturing,$

$TPM_{i,HSELVs,ReMfg} =$

$$PtCt_{i,HSELVs,ReMfg}\big[PtWt_{i,Neon}(\%VVeh_{HSELVs,T} + \%VVeh_{HSELVs,S} + \%VVeh_{HSELVs,C} + \%VVeh_{HSELVs,M}) + PtWt_{i,Voyager}(\%VVeh_{HSELVs,L} + \%VVeh_{HSELVs,W} + \%VVeh_{HSELVs,V}) + PtWt_{i,Explorer}(\%VVeh_{HSELVs,SP} + \%VVeh_{HSELVs,P})\big] \div 100, where:$$

$PtCt_{i,HSELVs,ReMfg} = Part\ Count\ for\ Part\ Type, i, from\ HSELVs\ sold\ for\ Remanufacture;$

$PtWt_{i,Neon} = Part\ Weight\ (kg) for\ Part\ Type, i, from\ 1997\ Neon;$

$PtWt_{i,Voyager} = Part\ Weight\ (kg) for\ Part\ Type, i, from\ 1996\ Voyager;$

$PtWt_{i,Explorer} = Part\ Weight\ (kg) for\ Part\ Type, i, from\ 1994\ Explorer$

$\%VVeh_{HSELVs,T} = \%\ Unit\ Volume\ HSELVs\ in\ Two\ seater (T)\ Vehicle\ Size\ Class;$

$\%VVeh_{HSELVs,S} = \%\ Unit\ Volume\ HSELVs\ in\ Subcompact (S)\ Vehicle\ Size\ Class;$

$\%VVeh_{HSELVs,C} = \%\ Unit\ Volume\ HSELVs\ in\ Compact (C)\ Vehicle\ Size\ Class;$

$\%VVeh_{HSELVs,M} = \%\ Unit\ Volume\ HSELVs\ in\ Midsize (M)\ Vehicle\ Size\ Class;$

$\%VVeh_{HSELVs,L} = \%\ Unit\ Volume\ HSELVs\ in\ Largesize (L)\ Vehicle\ Size\ Class;$

$\%VVeh_{HSELVs,W} = \%\ Unit\ Volume\ HSELVs\ in\ Station\ Wagon (W)\ Vehicle\ Size\ Class;$

$\%VVeh_{HSELVs,SP} = \%\ \mathit{Unit\ Volume\ HSELVs\ in\ Special\ Purpose(SP)\ Vehicle\ Size\ Class;}$

$\%VVeh_{HSELVs,P} = \%\ \mathit{Unit\ Volume\ HSELVs\ in\ Pickup(P)\ Vehicle\ Size\ Class.}$

ii. *Remanufacturable HSELV parts, by Part Type, per tonne HSELVs Processed:*

$$\frac{\mathit{kg\ HSELV\ Part\ Type,i,Sold\ for\ Remanufacture}}{\mathit{tonne\ HSELVs\ Processed}} =$$

$$\frac{TPM_{i,HSELVs,ReMfg}}{\mathit{kg\ HSELVs\ Processed\ in}\ 2005} \times \frac{1000\ kg}{\mathit{tonne}}$$

iii. *Remanufacturable HSELV parts, by Part Type, per tonne ELVs Processed:*

$$\frac{\mathit{kg\ HSELV\ Part\ Type,i,Sold\ for\ Remanufacture}}{\mathit{tonne\ ELVs\ Processed}} =$$

$$\frac{TPM_{i,HSELVs,ReMfg}}{\mathit{kg\ HSELVs} + \mathit{LSELVs\ Processed\ in}\ 2005} \times \frac{1000\ kg}{\mathit{tonne}}$$

iv. *Remanufacturable HSELV parts, by Part Type, per tonne ELVs and CORE Parts Processed:*

$$\frac{\mathit{kg\ HSELV\ Part\ Type,i,Sold\ for\ Remanufacture}}{\mathit{tonne\ ELVs\ \&\ CORE\ Parts\ Processed}} =$$

$$\frac{TPM_{i,HSELVs,ReMfg}}{\mathit{kg\ HSELVs} + \mathit{LSELVs} + \mathit{CORE\ Parts\ Processed\ in}\ 2005} \times \frac{1000\ kg}{\mathit{tonne}}$$

e. HSELV and LSELV Parts Directed For Recycling:

i. *Estimated Part Counts for HSELV Recycled Parts, by Part Type:*

a. Part Count for Regular Tires from HSELVs bound for Recycling, assuming each ELV enters the process with 4 regular tires, $PtCt_{RegTire,HSELVs,Recycle} =$

$(VehCt_{HSELVs,2005} \times 4) - PtCt_{RegTire,HSELVs,Reuse}$, *where*:

$VehCt_{HSELVs,2005} = \mathit{Vehicle\ Count\ for\ HSELVs\ processed\ in}\ 2005$

$PtCt_{RegTire,HSELVs,Reuse} = \mathit{Part\ Count\ for\ Regular\ Tires\ from\ HSELVs\ sold\ for\ Reuse}$

$= PtCt_{RegTire,ELVs,Reuse} \times 0.12$, and

$PtCt_{RegTire,ELVs,Reuse} = \mathit{Part\ Count\ for\ Regular\ Tires\ recovered\ from\ processed\ ELVs\ and\ sold\ for\ Reuse}$

b. Part Count for Spare Tires from HSELVs bound for Recycling, assuming each ELV enters the process with 1 spare tire, $PtCt_{SpareTire,HSELVs,Recycle} =$

$(VehCt_{HSELVs,2005} \times 1) - PtCt_{SpareTire,HSELVs,Reuse}$, *where*:

$VehCt_{HSELVs,2005} = \mathit{Vehicle\ Count\ for\ HSELVs\ processed\ in}\ 2005$

$PtCt_{SpareTire,HSELVs,Reuse} = \mathit{Part\ Count\ for\ Spare\ Tires\ from\ HSELVs\ sold\ for\ Reuse}$

$= PtCt_{SpareTire,ELVs,Reuse} \times 0.12$, and

$PtCt_{SpareTire,ELVs,Reuse}$ = Part Count for Spare Tires recovered from processed ELVs and sold for Reuse

c. Part Count for Catalytic Converters from HSELVs bound for Recycling, assuming each HSELV enters the process with 1 catalytic converter, $PtCt_{CatCon,HSELVs,Recycle} =$

$(VehCt_{HSELVs,2005} \times 1) - PtCt_{CatCon,HSELVs,Reuse}$, where:

$VehCt_{HSELVs,2005}$ = Vehicle Count for HSELVs processed in 2005

$PtCt_{CatCon,HSELVs,Reuse}$ = Part Count for Catalytic Converters from HSELVs sold for Reuse

d. Maximum Part Count for Batteries from HSELVs bound for Recycling, assuming each HSELV enters the process with 1 battery and all are recovered, $PtCt_{Max,Battery,HSELVs,Recycle} =$

$(VehCt_{HSELVs,2005} \times 1) - PtCt_{Battery,HSELVs,Reuse}$, where:

$VehCt_{HSELVs,2005}$ = Vehicle Count for HSELVs processed in 2005

$PtCt_{Battery,HSELVs,Reuse}$ = Part Count for Batteries from HSELVs sold for Reuse

e. Part Count for Batteries from HSELVs bound for Recycling, based on battery shipment weight data and given 12% of the dismantled vehicles are HSELVs, $PtCt_{Battery,HSELVs,Recycle} =$

$$\frac{kg\ Batteries\ Shipped\ for\ Recycling}{PtWt_{Avg,Battery}} \times 0.88, \text{ where:}$$

Estimated Average Weight per Battery, $PtWt_{Avg,Battery} =$

$$\frac{TPM_{Max,Battery,HSELVs,Recycle} + TPM_{Max,Battery,LSELVs,Recycle}}{PtCt_{Max,Battery,HSELVs,Recycle} + PtCt_{Max,Battery,LSELVs,Recycle}}, \text{ where:}$$

$TPM_{Max,Battery,HSELVs,Recycle}$ = Maximum Total Parts Mass (kg) of Batteries from HSELVsbound for Recycling,

$TPM_{Max,Battery,LSELVs,Recycle}$ = Maximum Total Parts Mass (kg) of Batteries from LSELVsbound for Recycling,

$PtCt_{Max,Battery,HSELVs,Recycle}$ = Maximum Part Count for Batteries from HSELVs bound forRecycling

$PtCt_{Max,Battery,LSELVs,Recycle}$ = Maximum Part Count for Batteries from LSELVs bound forRecycling

ii. <u>*Estimated Part Counts for LSELV Recycled Parts, by Part Type:*</u>

a. Part Count for Regular Tires from LSELVs bound for Recycling, assuming each ELV enters the process with 4 regular tires, $PtCt_{RegTire,LSELVs,Recycle} =$

$(VehCt_{LSELVs,2005} \times 4) - PtCt_{RegTire,LSELVs,Reuse}$, where:

$VehCt_{LSELVs,2005}$ = Vehicle Count for LSELVs processed in 2005

$PtCt_{RegTire,LSELVs,Reuse} = Part\ Count\ for\ Regular\ Tires\ from\ LSELVs\ sold\ for\ Reuse$

$= PtCt_{RegTire,ELVs,Reuse} \times 0.88$, and

$PtCt_{RegTire,ELVs,Reuse} = Part\ Count\ for\ Regular\ Tires\ recovered\ from\ processed\ ELVs\ and\ sold\ for\ Reuse$

b. Part Count for Spare Tires from LSELVs bound for Recycling, assuming each ELV enters the process with 1 spare tire, $PtCt_{SpareTire,LSELVs,Recycle} =$

$(VehCt_{LSELVs,2005} \times 1) - PtCt_{SpareTire,LSELVs,Reuse}$, where:

$VehCt_{LSELVs,2005} = Vehicle\ Count\ for\ LSELVs\ processed\ in\ 2005$

$PtCt_{SpareTire,LSELVs,Reuse} = Part\ Count\ for\ Spare\ Tires\ from\ LSELVs\ sold\ for\ Reuse$

$= PtCt_{SpareTire,ELVs,Reuse} \times 0.88$, and

$PtCt_{SpareTire,ELVs,Reuse} = Part\ Count\ for\ Spare\ Tires\ recovered\ from\ processed\ ELVs\ and\ sold\ for\ Reuse$

c. Part Count for Catalytic Converters from LSELVs bound for Recycling, assuming each ELV entering the process, with a model year ≥ 1975, has atleast 1 catalytic converter, $PtCt_{CatCon,HSELVs,Recycle} =$

$(VehCt_{LSELVs,2005} \times 1) - PtCt_{CatCon,LSELVs,Reuse}$, where:

$VehCt_{LSELVs,2005} = Vehicle\ Count\ for\ LSELVs\ processed\ in\ 2005$

$PtCt_{CatCon,LSELVs,Reuse} = Part\ Count\ for\ Catalytic\ Converters\ from\ LSELVs\ sold\ for\ Reuse$

d. Maximum Part Count for Batteries from LSELVs bound for Recycling, assuming each LSELV enters the process with 1 battery and all are recovered, $PtCt_{Max,Battery,LSELVs,Recycle} =$

$(VehCt_{LSELVs,2005} \times 1) - PtCt_{Battery,LSELVs,Reuse}$, where:

$VehCt_{LSELVs,2005} = Vehicle\ Count\ for\ LSELVs\ processed\ in\ 2005$

$PtCt_{Battery,LSELVs,Reuse} = Part\ Count\ for\ Batteries\ from\ LSELVs\ sold\ for\ Reuse$

e. Part Count for Batteries from LSELVs bound for Recycling, based on battery shipment weight data and given 88% of the dismantled vehicles are LSELVs, $PtCt_{Battery,HSELVs,Recycle} =$

$$\frac{kg\ Batteries\ Shipped\ for\ Recycling}{PtWt_{Avg,Battery}} \times 0.12, where:$$

$Estimated\ Average\ Weight\ per\ Battery, PtWt_{Avg,Battery} =$

$$\frac{TPM_{Max,Battery,HSELVs,Recycle} + TPM_{Max,Battery,LSELVs,Recycle}}{PtCt_{Max,Battery,HSELVs,Recycle} + PtCt_{Max,Battery,LSELVs,Recycle}}, where:$$

$TPM_{Max,Battery,HSELVs,Recycle} = Maximum\ Total\ Parts\ Mass\ (kg) of\ Batteries\ from\ HSELVs\ bound\ for\ Recycling,$

$TPM_{Max,Battery,LSELVs,Recycle}$ = Maximum Total Parts Mass (kg) of Batteries from LSELVsbound for Recycling,

$PtCt_{Max,Battery,HSELVs,Recycle}$ = Maximum Part Count for Batteries from HSELVs bound forRecycling

$PtCt_{Max,Battery,LSELVs,Recycle}$ = Maximum Part Count for Batteries from LSELVs bound for Recycling

iii. Mass of Recycled HSELV parts, by Part Type:

a. Total Parts Mass (kg) for Part Type, i, from HSELVs bound for Recycling, where i = Regular Tire, Spare Tire, or Catalytic Converter, $TPM_{i,HSELVs,Recycle}$ =

$$PtCt_{i,HSELVs,Recycle}\left[PtWt_{i,Neon}\left(\%VVeh_{HSELVs,T} + \%VVeh_{HSELVs,S} + \%VVeh_{HSELVs,C} + \%VVeh_{HSELVs,M}\right) + PtWt_{i,Voyager}\left(\%VVeh_{HSELVs,L} + \%VVeh_{HSELVs,W} + \%VVeh_{HSELVs,V}\right) + PtWt_{i,Explorer}\left(\%VVeh_{HSELVs,SP} + \%VVeh_{HSELVs,P}\right)\right] \div 100, \text{where:}$$

$PtCt_{i,HSELVs,Recycle}$ = Part Count for Part Type, i, from HSELVs sold for Recycling;

$PtWt_{i,Neon}$ = Part Weight (kg) for Part Type, i, from 1997 Neon;

$PtWt_{i,Voyager}$ = Part Weight (kg) for Part Type, i, from 1996 Voyager;

$PtWt_{i,Explorer}$ = Part Weight (kg) for Part Type, i, from 1994 Explorer

$\%VVeh_{HSELVs,T}$ = % Unit Volume HSELVs in Two seater(T) Vehicle Size Class;

$\%VVeh_{HSELVs,S}$ = % Unit Volume HSELVs in Subcompact(S) Vehicle Size Class;

$\%VVeh_{HSELVs,C}$ = % Unit Volume HSELVs in Compact(C) Vehicle Size Class;

$\%VVeh_{HSELVs,M}$ = % Unit Volume HSELVs in Midsize(M) Vehicle Size Class;

$\%VVeh_{HSELVs,L}$ = % Unit Volume HSELVs in Largesize(L) Vehicle Size Class;

$\%VVeh_{HSELVs,W}$ = % Unit Volume HSELVs in Station Wagon(W) Vehicle Size Class;

$\%VVeh_{HSELVs,SP}$ = % Unit Volume HSELVs in Special Purpose(SP) Vehicle Size Class;

$\%VVeh_{HSELVs,P}$ = % Unit Volume HSELVs in Pickup(P) Vehicle Size Class.

b. Maximum Total Parts Mass (kg) of Batteries from HSELVs bound for Recycling, $TPM_{Max,Battery,HSELVs,Recycle}$ =

$$PtCt_{Max,Battery,HSELVs,Recycle}\left[PtWt_{Battery,Neon}\left(\%VVeh_{HSELVs,T} + \%VVeh_{HSELVs,S} + \%VVeh_{HSELVs,C} + \%VVeh_{HSELVs,M}\right) + PtWt_{Battery,Voyager}\left(\%VVeh_{HSELVs,L} + \%VVeh_{HSELVs,W} + \%VVeh_{HSELVs,V}\right) + PtWt_{Battery,Explorer}\left(\%VVeh_{HSELVs,SP} + \%VVeh_{HSELVs,P}\right)\right] \div 100, \text{where:}$$

$PtCt_{Max,Battery,HSELVs,Recycle}$ = Maximum Part Count for Batteries from HSELVs sold for Recycling;

$PtWt_{Battery,Neon}$ = Part Weight (kg) for Battery from 1997 Neon;

$PtWt_{Battery,Voyager}$ = Part Weight (kg) for Battery from 1996 Voyager;

$PtWt_{Battery,Explorer}$ = Part Weight (kg) for Battery from 1994 Explorer

$\%VVeh_{HSELVs,T}$ = % Unit Volume HSELVs in Two seater(T) Vehicle Size Class;
$\%VVeh_{HSELVs,S}$ = % Unit Volume HSELVs in Subcompact(S) Vehicle Size Class;
$\%VVeh_{HSELVs,C}$ = % Unit Volume HSELVs in Compact(C) Vehicle Size Class;
$\%VVeh_{HSELVs,M}$ = % Unit Volume HSELVs in Midsize(M) Vehicle Size Class;
$\%VVeh_{HSELVs,L}$ = % Unit Volume HSELVs in Largesize(L) Vehicle Size Class;
$\%VVeh_{HSELVs,W}$ = % Unit Volume HSELVs in Station Wagon(W) Vehicle Size Class;
$\%VVeh_{HSELVs,SP}$ = % Unit Volume HSELVs in Special Purpose(SP) Vehicle Size Class;
$\%VVeh_{HSELVs,P}$ = % Unit Volume HSELVs in Pickup(P) Vehicle Size Class.

c. Total Parts Mass (kg) of Batteries from HSELVs shipped for Recycling, $TPM_{Batteries,HSELVs,Recycle}$ =

$$PtCt_{Battery,HSELVs,Recycle}\big[PtWt_{Battery,Neon}(\%VVeh_{HSELVs,T} + \%VVeh_{HSELVs,S} + \%VVeh_{HSELVs,C} + \%VVeh_{HSELVs,M}) + PtWt_{Battery,Voyager}(\%VVeh_{HSELVs,L} + \%VVeh_{HSELVs,W} + \%VVeh_{HSELVs,V}) + PtWt_{Battery,Explorer}(\%VVeh_{HSELVs,SP} + \%VVeh_{HSELVs,P})\big] \div 100, \text{where:}$$

$PtCt_{Battery,HSELVs,Recycle}$ = Part Count for Batteries from HSELVs sold for Recycling;
$PtWt_{Battery,Neon}$ = Part Weight (kg) for Battery, from 1997 Neon;
$PtWt_{Battery,Voyager}$ = Part Weight (kg) for Battery from 1996 Voyager;
$PtWt_{Battery,Explorer}$ = Part Weight (kg) for Battery from 1994 Explorer
$\%VVeh_{HSELVs,T}$ = % Unit Volume HSELVs in Two seater(T) Vehicle Size Class;
$\%VVeh_{HSELVs,S}$ = % Unit Volume HSELVs in Subcompact(S) Vehicle Size Class;
$\%VVeh_{HSELVs,C}$ = % Unit Volume HSELVs in Compact(C) Vehicle Size Class;
$\%VVeh_{HSELVs,M}$ = % Unit Volume HSELVs in Midsize(M) Vehicle Size Class;
$\%VVeh_{HSELVs,L}$ = % Unit Volume HSELVs in Largesize(L) Vehicle Size Class;
$\%VVeh_{HSELVs,W}$ = % Unit Volume HSELVs in Station Wagon(W) Vehicle Size Class;
$\%VVeh_{HSELVs,SP}$ = % Unit Volume HSELVs in Special Purpose(SP) Vehicle Size Class;
$\%VVeh_{HSELVs,P}$ = % Unit Volume HSELVs in Pickup(P) Vehicle Size Class;

Further $TPM_{Batteries,HSELVs,Recycle} \cong TPM_{Batteries,ELVs,Recycle} \times 0.12$, where:
$TPM_{Batteries,ELVs,Reuse}$ = Total Parts Mass (kg) of Batteries recovered from ELVs and shipped for Recycling

iv. Mass of Recycled LSELV parts, by Part Type:

a. Total Parts Mass (kg) for Part Type, i, from LSELVs bound for Recycling, where i = Regular Tire, Spare Tire, or Catalytic Converter, $TPM_{i,LSELVs,Recycle}$ =

$$\begin{aligned}&PtCt_{i,LSELVs,Recycle}\Bigg[PtWt_{i,Neon}\big(\%VVeh_{LSELVs,T}+\%VVeh_{LSELVs,S}+\%VVeh_{LSELVs,C}\\&\quad+\%VVeh_{LSELVs,M}\big)+PtWt_{i,Voyager}\big(\%VVeh_{LSELVs,L}+\%VVeh_{LSELVs,W}+\%VVeh_{LSELVs,V}\big)\\&\quad+PtWt_{i,Explorer}\big(\%VVeh_{LSELVs,SP}+\%VVeh_{LSELVs,P}\big)\\&\quad+\%VVeh_{LSELVs,U}\frac{\big(PtWt_{i,Neon}+PtWt_{i,Voyager}+PtWt_{i,Explorer}\big)}{3}\Bigg]\div 100, where:\end{aligned}$$

$PtCt_{i,LSELVs,Recycle} = Part\ Count\ for\ Part\ Type, i, from\ LSELVs\ sold\ for\ Recycling;$

$PtWt_{i,Neon} = Part\ Weight\ (kg) for\ Part\ Type, i, from\ 1997\ Neon;$

$PtWt_{i,Voyager} = Part\ Weight\ (kg) for\ Part\ Type, i, from\ 1996\ Voyager;$

$PtWt_{i,Explorer} = Part\ Weight\ (kg) for\ Part\ Type, i, from\ 1994\ Explorer$

$\%VVeh_{LSELVs,T} = \%\ Unit\ Volume\ LSELVs\ in\ Two\ seater(T)\ Vehicle\ Size\ Class;$

$\%VVeh_{LSELVs,S} = \%\ Unit\ Volume\ LSELVs\ in\ Subcompact(S)\ Vehicle\ Size\ Class;$

$\%VVeh_{LSELVs,C} = \%\ Unit\ Volume\ LSELVs\ in\ Compact(C)\ Vehicle\ Size\ Class;$

$\%VVeh_{LSELVs,M} = \%\ Unit\ Volume\ LSELVs\ in\ Midsize(M)\ Vehicle\ Size\ Class;$

$\%VVeh_{LSELVs,L} = \%\ Unit\ Volume\ LSELVs\ in\ Largesize(L)\ Vehicle\ Size\ Class;$

$\%VVeh_{LSELVs,W} = \%\ Unit\ Volume\ LSELVs\ in\ Station\ Wagon(W)\ Vehicle\ Size\ Class;$

$\%VVeh_{LSELVs,SP} = \%\ Unit\ Volume\ LSELVs\ in\ Special\ Purpose(SP)\ Vehicle\ Size\ Class;$

$\%VVeh_{LSELVs,P} = \%\ Unit\ Volume\ LSELVs\ in\ Pickup(P)\ Vehicle\ Size\ Class.$

$\%VVeh_{LSELVs,U} = \%\ Unit\ Volume\ LSELVs\ in\ Unknown(U)\ Vehicle\ Size\ Class$

b. Maximum Total Parts Mass (kg) of Batteries from LSELVs bound for Recycling,

$TPM_{Max,Battery,LSELVs,Recycle} =$

$$\begin{aligned}&PtCt_{Max,Battery,LSELVs,Recycle}\Bigg[PtWt_{Battery,Neon}\big(\%VVeh_{LSELVs,T}+\%VVeh_{LSELVs,S}+\%VVeh_{LSELVs,C}\\&\quad+\%VVeh_{LSELVs,M}\big)+PtWt_{i,Voyager}\big(\%VVeh_{LSELVs,L}+\%VVeh_{LSELVs,W}+\%VVeh_{LSELVs,V}\big)\\&\quad+PtWt_{Battery,Explorer}\big(\%VVeh_{LSELVs,SP}+\%VVeh_{LSELVs,P}\big)\\&\quad+\%VVeh_{LSELVs,U}\frac{\big(PtWt_{i,Neon}+PtWt_{i,Voyager}+PtWt_{i,Explorer}\big)}{3}\Bigg]\div 100, where:\end{aligned}$$

$PtCt_{Max,Battery,LSELVs,Recycle} = Maximum\ Part\ Count\ for\ Batteries\ from\ LSELVs\ sold\ for\ Recycling;$

$PtWt_{Battery,Neon} = Part\ Weight\ (kg) for\ Battery\ from\ 1997\ Neon;$

$PtWt_{Battery,Voyager} = Part\ Weight\ (kg) for\ Battery\ from\ 1996\ Voyager;$

$PtWt_{Battery,Explorer} = Part\ Weight\ (kg) for\ Battery\ from\ 1994\ Explorer$

$\%VVeh_{LSELVs,T} = \%\ Unit\ Volume\ LSELVs\ in\ Two\ seater(T)\ Vehicle\ Size\ Class;$

$\%VVeh_{LSELVs,S} = \%\ Unit\ Volume\ LSELVs\ in\ Subcompact(S)\ Vehicle\ Size\ Class;$

$\%VVeh_{LSELVs,C} = \%\ Unit\ Volume\ LSELVs\ in\ Compact(C)\ Vehicle\ Size\ Class;$

$\%VVeh_{LSELVs,M}$ = % *Unit Volume LSELVs in Midsize*(M) *Vehicle Size Class;*
$\%VVeh_{LSELVs,L}$ = % *Unit Volume LSELVs in Largesize*(L) *Vehicle Size Class;*
$\%VVeh_{LSELVs,W}$ = % *Unit Volume LSELVs in Station Wagon*(W) *Vehicle Size Class;*
$\%VVeh_{LSELVs,SP}$ = % *Unit Volume LSELVs in Special Purpose*(SP) *Vehicle Size Class;*
$\%VVeh_{LSELVs,P}$ = % *Unit Volume LSELVs in Pickup*(P) *Vehicle Size Class.*
$\%VVeh_{LSELVs,U}$ = % *Unit Volume LSELVs in Unknown*(U) *Vehicle Size Class*

c. Total Parts Mass (kg) of Batteries from LSELVs shipped for Recycling,

$$TPM_{Batteries,LSELVs,Recycle} = PtCt_{Battery,LSELVs,Recycle}\Bigg[PtWt_{Battery,Neon}\left(\%VVeh_{LSELVs,T} + \%VVeh_{LSELVs,S} + \%VVeh_{LSELVs,C} + \%VVeh_{LSELVs,M}\right) + PtWt_{Battery,Voyager}\left(\%VVeh_{LSELVs,L} + \%VVeh_{LSELVs,W} + \%VVeh_{LSELVs,V}\right) + PtWt_{Battery,Explorer}\left(\%VVeh_{LSELVs,SP} + \%VVeh_{LSELVs,P}\right) + \%VVeh_{LSELVs,U}\frac{\left(PtWt_{i,Neon} + PtWt_{i,Voyager} + PtWt_{i,Explorer}\right)}{3}\Bigg] \div 100, \mathit{where:}$$

$PtCt_{Battery,LSELVs,Recycle}$ = *Part Count for Batteries from LSELVs sold for Recycling;*
$PtWt_{Battery,Neon}$ = *Part Weight (kg) for Battery from* 1997 *Neon;*
$PtWt_{Battery,Voyager}$ = *Part Weight (kg) for Battery from* 1996 *Voyager;*
$PtWt_{Battery,Explorer}$ = *Part Weight (kg) for Battery from* 1994 *Explorer*
$\%VVeh_{LSELVs,T}$ = % *Unit Volume LSELVs in Two seater*(T) *Vehicle Size Class;*
$\%VVeh_{LSELVs,S}$ = % *Unit Volume LSELVs in Subcompact*(S) *Vehicle Size Class;*
$\%VVeh_{LSELVs,C}$ = % *Unit Volume LSELVs in Compact*(C) *Vehicle Size Class;*
$\%VVeh_{LSELVs,M}$ = % *Unit Volume LSELVs in Midsize*(M) *Vehicle Size Class;*
$\%VVeh_{LSELVs,L}$ = % *Unit Volume LSELVs in Largesize*(L) *Vehicle Size Class;*
$\%VVeh_{LSELVs,W}$ = % *Unit Volume LSELVs in Station Wagon*(W) *Vehicle Size Class;*
$\%VVeh_{LSELVs,SP}$ = % *Unit Volume LSELVs in Special Purpose*(SP) *Vehicle Size Class;*
$\%VVeh_{LSELVs,P}$ = % *Unit Volume LSELVs in Pickup*(P) *Vehicle Size Class.*
$\%VVeh_{LSELVs,U}$ = % *Unit Volume LSELVs in Unknown*(U) *Vehicle Size Class*

Further $TPM_{Batteries,LSELVs,Recycle} \cong TPM_{Batteries,ELVs,Recycle} \times 0.88$, where:
$TPM_{Batteries,ELVs,Reuse}$ = *Total Parts Mass (kg) of Batteries recovered from ELVs and shipped for Recycling*

v. Recycled HSELV parts, by Part Type, per tonne HSELVs Processed:

$$\frac{kg\ HSELV\ Part\ Type, i, Sold\ for\ Recycling}{tonne\ HSELVs\ Processed} = \frac{TPM_{i,HSELVs,Recycle}}{kg\ HSELVs\ Processed\ in\ 2005} \times \frac{1000\ kg}{tonne}$$

vi. *Recycled HSELV parts, by Part Type, per tonne ELVs Processed:*

$$\frac{kg\ HSELV\ Part\ Type, i, Sold\ for\ Recycling}{tonne\ ELVs\ Processed} =$$
$$\frac{TPM_{i,HSELVs,Recycle}}{kg\ HSELVs + LSELVs\ Processed\ in\ 2005} \times \frac{1000\ kg}{tonne}$$

vii. *Recycled HSELV parts, by Part Type, per tonne ELVs and CORE Parts Processed:*

$$\frac{kg\ HSELV\ Part\ Type, i, Sold\ for\ Recycling}{tonne\ ELVs\ \&\ CORE\ Parts\ Processed} =$$
$$\frac{TPM_{i,HSELVs,Recycle}}{kg\ HSELVs + LSELVs + CORE\ Parts\ Processed\ in\ 2005} \times \frac{1000\ kg}{tonne}$$

viii. *Recycled LSELV parts, by Part Type, per tonne HSELVs Processed:*

$$\frac{kg\ LSELV\ Part\ Type, i, Sold\ for\ Recycling}{tonne\ LSELVs\ Processed} =$$
$$\frac{TPM_{i,LSELVs,Recycle}}{kg\ LSELVs\ Processed\ in\ 2005} \times \frac{1000\ kg}{tonne}$$

ix. *Recycled LSELV parts, by Part Type, per tonne ELVs Processed:*

$$\frac{kg\ LSELV\ Part\ Type, i, Sold\ for\ Recycling}{tonne\ ELVs\ Processed} =$$
$$\frac{TPM_{i,LSELVs,Recycle}}{kg\ HSELVs + LSELVs\ Processed\ in\ 2005} \times \frac{1000\ kg}{tonne}$$

x. *Recycled LSELV parts, by Part Type, per tonne ELVs and CORE Parts Processed:*

$$\frac{kg\ LSELV\ Part\ Type, i, Sold\ for\ Recycling}{tonne\ ELVs\ \&\ CORE\ Parts\ Processed} =$$
$$\frac{TPM_{i,LSELVs,Recycle}}{kg\ HSELVs + LSELVs + CORE\ Parts\ Processed\ in\ 2005} \times \frac{1000\ kg}{tonne}$$

f. Fluids Recovered from Processed ELVs:

i. *Mass of Recovered ELV Fluids, by Fluid Type:*

$$Total\ Fluid\ Weight\ for\ Fluid\ Type, f, recovered\ from\ ELVs, TFWt_{f,ELVs} =$$
$$= VehCt_{ELVs}\left[\frac{\left(RFWt_{f,Neon} + RFWt_{f,Voyager} + RFWt_{f,Explorer}\right)}{3}\right], where:$$

$VehCt_{ELVs} = Vehicle\ Count\ for\ total\ ELVs\ processed;$

$RFWt_{f,Neon} = Recovered\ Fluid\ Weight\ (kg) for\ Fluid\ Type, f, from\ 1997\ Neon;$

$RFWt_{Antifreeze,Voyager} = Recovered\ Fluid\ (kg) for\ Fluid\ Type, f, from\ 1996\ Voyager;$

$RFWt_{Antifreeze,Explorer}$ = Recovered Fluid (kg) for Fluid Type, f, from 1994 Explorer; where Fluid Type, f, is Engine Oil, Transmission Oil, Power Steering Fluid, Antifreeze, Windshield Washer Fluid, or Gasoline.

ii. Recovered ELV Fluids, by Fluid Type, per tonne ELVs Processed:

$$\frac{kg\ Recovered\ ELV\ Fluid\ Type, f}{tonne\ ELVs\ Processed} = \frac{TFWt_{i,ELVs}}{kg\ HSELVs + LSELVs\ Processed\ in\ 2005} \times \frac{1000\ kg}{tonne}$$

iii. Recovered ELV Fluids, by Fluid Type, per tonne ELVs and CORE Parts Processed:

$$\frac{kg\ Recovered\ ELV\ Fluid\ Type, f}{tonne\ ELVs\ \&\ CORE\ Parts\ Processed} = \frac{TFWt_{i,ELVs}}{kg\ HSELVs + LSELVs + CORE\ Parts\ Processed\ in\ 2005} \times \frac{1000\ kg}{tonne}$$

g. HSELV Parts Deleted from Inventory:

i. Mass of HSELV parts Deleted from Inventory, by Part Type:

Total Parts Mass (kg) of Part Type, i, from HSELVs Deleted from inventory,

$$TPM_{i,HSELVs,Delete} = PtCt_{i,HSELVs,Delete}\left[PtWt_{i,Neon}\left(\%VVeh_{HSELVs,T} + \%VVeh_{HSELVs,S} + \%VVeh_{HSELVs,C} + \%VVeh_{HSELVs,M}\right) + PtWt_{i,Voyager}\left(\%VVeh_{HSELVs,L} + \%VVeh_{HSELVs,W} + \%VVeh_{HSELVs,V}\right) + PtWt_{i,Explorer}\left(\%VVeh_{HSELVs,SP} + \%VVeh_{HSELVs,P}\right)\right] \div 100,\ where:$$

$PtCt_{i,HSELVs,Delete}$ = Part Count for Part Type, i, from HSELVs Deleted from inventory;

$PtWt_{i,Neon}$ = Part Weight (kg) for Part Type, i, from 1997 Neon;

$PtWt_{i,Voyager}$ = Part Weight (kg) for Part Type, i, from 1996 Voyager;

$PtWt_{i,Explorer}$ = Part Weight (kg) for Part Type, i, from 1994 Explorer;

$\%VVeh_{HSELVs,T}$ = % Unit Volume HSELVs in Two seater (T) Vehicle Size Class;

$\%VVeh_{HSELVs,S}$ = % Unit Volume HSELVs in Subcompact (S) Vehicle Size Class;

$\%VVeh_{HSELVs,C}$ = % Unit Volume HSELVs in Compact (C) Vehicle Size Class;

$\%VVeh_{HSELVs,M}$ = % Unit Volume HSELVs in Midsize (M) Vehicle Size Class;

$\%VVeh_{HSELVs,L}$ = % Unit Volume HSELVs in Largesize (L) Vehicle Size Class;

$\%VVeh_{HSELVs,W}$ = % Unit Volume HSELVs in Station Wagon (W) Vehicle Size Class;

$\%VVeh_{HSELVs,SP}$ = % Unit Volume HSELVs in Special Purpose (SP) Vehicle Size Class;

$\%VVeh_{HSELVs,P}$ = % Unit Volume HSELVs in Pickup (P) Vehicle Size Class.

ii. *HSELV parts Deleted from Inventory, by Part Type, per tonne HSELVs Processed:*

$$\frac{kg\ HSELV\ Part\ Type, i, Deleted\ from\ Inventory}{tonne\ HSELVs\ Processed} = \frac{TPM_{i,HSELVs,Delete}}{kg\ HSELVs\ Processed\ in\ 2005} \times \frac{1000\ kg}{tonne}$$

iii. *HSELV parts Deleted from Inventory, by Part Type, per tonne ELVs Processed:*

$$\frac{kg\ HSELV\ Part\ Type, i, Deleted\ from\ Inventory}{tonne\ ELVs\ Processed} = \frac{TPM_{i,HSELVs,Delete}}{kg\ HSELVs + LSELVs\ Processed\ in\ 2005} \times \frac{1000\ kg}{tonne}$$

iv. *HSELV parts Deleted from Inventory, by Part Type, per tonne ELVs and CORE Parts Processed:*

$$\frac{kg\ HSELV\ Part\ Type, i, Deleted\ from\ Inventory}{tonne\ ELVs\ \&\ CORE\ Parts\ Processed} = \frac{TPM_{i,HSELVs,Delete}}{kg\ HSELVs + LSELVs + Core\ Parts\ Processed\ in\ 2005} \times \frac{1000\ kg}{tonne}$$

h. ELV Hulks and Parts Shipped for Shredding:

i. *Mass of ELV Hulks and Parts Shipped for Shredding:*

$$Total\ Mass\ (kg) of\ ELV\ Hulks, Deleted\ Parts\ and\ CORE\ Parts\ Shipped\ for\ Shredding,$$

$$TM_{ELV\ Hulks\&Parts,Shredding} =$$

$$(TVM_{HSELVs,Received} + TVM_{LSELVs,Received} + TPM_{CORE\ Pts,Received})$$
$$- (TPM_{HSELV\ Pts,Reuse} + TPM_{LSELV\ Pts,Reuse} + TPM_{CORE\ Pt,Reuse} + TPM_{HSELV\ Pt,ReMfg}$$
$$+ TPM_{HSELV\ Pts,Recycle} + TPM_{LSELV\ Pts,Recycle} + TFWt_{ELVs}) + TPM_{HSELV\ Pts,Delete}, where:$$

$TVM_{HSELVs,Received} = Total\ Vehicle\ Mass\ (kg) of\ HSELVs\ Received\ and\ processed$

$TVM_{LSELVs,Received} = Total\ Vehicle\ Mass\ (kg) of\ LSELVs\ Received\ and\ processed$

$TPM_{CORE\ Pts,Received} = Total\ Parts\ Mass\ (kg) of\ CORE\ Parts\ Received\ and\ processed$

$TPM_{HSELV\ Pts,Reuse} = Total\ Parts\ Mass\ (kg) of\ HSELV\ Parts\ sold\ for\ Reuse$

$TPM_{LSELV\ Pts,Reuse} = Total\ Parts\ Mass\ (kg) of\ LSELV\ Parts\ sold\ for\ Reuse$

$TPM_{CORE\ Pt,Reuse} = Total\ Parts\ Mass\ (kg) of\ CORE\ Parts\ sold\ for\ Reuse$

$TPM_{HSELV\ Pt,ReMfg} = Total\ Parts\ Mass\ (kg) of\ HSELV\ Parts\ sold\ for\ Remanufacture$

$TPM_{HSELV\ Pts,Recycle} = Total\ Parts\ Mass\ (kg) of\ HSELV\ Parts\ sold\ for\ Recycling$
$(i.e. pre\text{-}shredder\ recycling; parts\ recycled\ independently\ of$
$hulks\ \&\ material\ shipped\ for\ shredding)$

$$TPM_{LSELV\ Pts,Recycle} = Total\ Parts\ Mass\ (kg) of\ LSELV\ Parts\ sold\ for\ Recycling\ (i.e.\ pre\text{-}shredder\ recycling)$$

$$TFWt_{ELVs} = Total\ Weight\ of\ Fluids\ recovered\ from\ ELVs,$$

$$TPM_{HSELV\ Pts,Delete} = Total\ Parts\ Mass\ (kg)\ of\ HSELVs\ Parts\ Deleted\ from\ inventory$$

ii. <u>ELV Hulks and Parts Shipped for Shredding, per tonne ELVs and CORE Parts Processed:</u>

$$\frac{kg\ ELV\ Hulks\ \&\ Parts\ Shipped\ for\ Shredding}{tonne\ ELVs\ \&\ CORE\ Parts\ Processed} = \frac{TM_{ELV\ Hulks\&Parts,Shredding}}{kg\ HSELVs + LSELVs + Core\ Parts\ Processed\ in\ 2005} \times \frac{1000\ kg}{tonne}$$

3) SHREDDING PROCESS INPUTS:

b. ELV Hulks:

$$\frac{kg\ ELVs}{tonne\ Shredder\ Feed} = \frac{tonnes\ ELVs\ Processed\ in\ 2005}{tonnes\ ELVs\ +\ Mixed\ Oversized\ Clips\ Processed\ in\ 2005} \times \frac{1000\ kg}{tonne}$$

$$= 571.5\ kg/tonne\ Shredder\ Feed$$

c. Mixed Oversize Clips (MOC):

$$\frac{kg\ Mixed\ Oversize\ Clips}{tonne\ shredder\ feed} = \frac{tonnes\ MOC\ Processed\ in\ 2005}{tonnes\ ELVs\ +\ MOC\ Processed\ in\ 2005} \times \frac{1000\ kg}{tonne}$$

$$= 419.8\ kg/tonne\ Shredder\ Feed$$

d. Electrical Energy:

$$\frac{kW\text{-}hr\ Electrical\ Energy}{tonne\ shredder\ feed} = \frac{kW\text{-}hr\ Elect\ in\ 2005}{tonnes\ ELVs\ +\ MOC\ Processed\ in\ 2005}$$

$$= 28.8\ kW\text{-}hr/tonne\ Shredder\ Feed$$

e. Process Water:

$$\frac{liters\ Process\ Water}{tonne\ shredder\ feed} = \frac{Average\ Process\ Water\ Addition, liter/hr}{\left(\frac{tonnes\ ELVs\ +\ MOC\ Processed\ in\ 2005}{Total\ Shredder\ Operating\ Hours\ in\ 2005}\right)}$$

$$= 5.5\ liters/tonne\ Shredder\ Feed$$

4) SHREDDING PROCESS OUTPUTS:

a. Total Shredded Ferrous Product Output:

$$\frac{kg\ Total\ Shredded\ Ferrous\ Product}{tonne\ Shredder\ Feed} = \frac{tonnes\ Shredded\ Ferrous\ Produced\ in\ 2005}{tonnes\ ELVs\ +\ MOC\ Processed\ in\ 2005} \times \frac{1000\ kg}{tonne}$$

$$= 775.3\ kg/tonne\ Shredder\ Feed$$

b. Ferrous Metals Recovered in Shredded Ferrous Product:

$$\frac{kg\ Ferrous\ Metals\ Recovered}{tonne\ Shredder\ Feed} = \frac{tonnes\ Shredded\ Ferrous\ Produced\ in\ 2005}{tonnes\ ELVs\ +\ MOC\ Processed\ in\ 2005} \times \frac{1000\ kg}{tonne} \times 0.92$$

$$= 713.3\ kg/tonne\ Shredder\ Feed$$

c. Non-Ferrous Metal & Non-metal Losses in Shredded Ferrous Product:

$$\frac{kg\ Non\text{-}Ferrous\ Metal\ \&\ Non\text{-}Metal\ Losses\ in\ Ferrous\ Product}{tonne\ Shredder\ Feed} =$$

$$\frac{tonnes\ Shredded\ Ferrous\ Produced\ in\ 2005}{tonnes\ ELVs\ +\ MOC\ Processed\ in\ 2005} \times \frac{1000\ kg}{tonne} \times 0.08\ = 62.0\ kg/tonne\ Shredder\ Feed$$

d. Total Non-Ferrous Residue Output:

$$\frac{kg\ Total\ Non\text{-}Ferrous\ Residue\ Output}{tonne\ Shredder\ Feed} = \frac{tonnes\ Non\text{-}Ferrous\ Residue\ Produced\ in\ 2005}{tonnes\ ELVs\ +\ MOC\ Processed\ in\ 2005}$$

$$\times \frac{1000\ kg}{tonne}$$

$$= 32.6\ kg/tonne\ Shredder\ Feed$$

e. Non-Ferrous Metals Recovered in Non-Ferrous Residue:

$$\frac{kg\ Non\text{-}Ferrous\ Metals\ Recovered}{tonne\ Shredder\ Feed} = \frac{tonnes\ Non\text{-}Ferrous\ Residue\ Produced\ in\ 2005}{tonnes\ ELVs\ +\ MOC\ Processed\ in\ 2005}$$

$$\times \frac{1000\ kg}{tonne} \times 0.80$$

$$= 26.1\ kg/tonne\ Shredder\ Feed$$

f. Ferrous Metals Losses in Non-Ferrous Residue:

$$\frac{kg\ Ferrous\ Metal\ Losses\ in\ Non\text{-}Ferrous\ Residue}{tonne\ Shredder\ Feed} =$$

$$\frac{tonnes\ Non\text{-}Ferrous\ Residue\ Produced\ in\ 2005}{tonnes\ ELVs\ +\ MOC\ Processed\ in\ 2005} \times \frac{1000\ kg}{tonne} \times 0.02 = 0.7\ kg/tonne\ Shredder\ Feed$$

g. Non-Metal Losses in Non-Ferrous Residue:

$$\frac{kg\ Non\text{-}Metal\ Losses\ in\ Non\text{-}Ferrous\ Residue}{tonne\ Shredder\ Feed} =$$

$$\frac{tonnes\ Non\text{-}Ferrous\ Residue\ Produced\ in\ 2005}{tonnes\ ELVs\ +\ MOC\ Processed\ in\ 2005} \times \frac{1000\ kg}{tonne} \times 0.18 = 5.9\ kg/tonne\ Shredder\ Feed$$

h. Shredder Residue:

$$\frac{kg\ Shredder\ Residue}{tonne\ Shredder\ Feed} = \frac{tonnes\ Shredder\ Residue\ Produced\ in\ 2005}{tonnes\ ELVs\ +\ MOC\ Processed\ in\ 2005} \times \frac{1000\ kg}{tonne}$$

$$= 192.1\ kg/tonne\ Shredder\ Feed$$

i. CO_2 Emissions from Electrical Power Generation, Excluding Grid Losses:

$$\frac{kg\ CO2}{tonne\ Shredder\ Feed} = \frac{278.32\ Tonnes\ CO2}{Net\ GW\text{-}hr} \times \frac{28.8\ kW\text{-}hr}{tonne\ Shredder\ Feed} \times \frac{GW\text{-}hr}{10^6\ kW\text{-}hr} \times \frac{1000\ kg}{tonne}$$

$$= 8.0\ kg/tonne\ Shredder\ Feed$$

j. SO_2 Emissions from Electrical Power Generation, Excluding Grid Losses:

$$\frac{g\ SO2}{tonne\ Shredder\ Feed} = \frac{1.05\ Tonnes\ SO2}{Net\ GW\text{-}hr} \times \frac{28.8\ kW\text{-}hr}{tonne\ Shredder\ Feed} \times \frac{GW\text{-}hr}{10^6\ kW\text{-}hr} \times \frac{10^6\ g}{tonne}$$

$$= 30.2\ g/tonne\ Shredder\ Feed$$

k. NO_X (as NO_2) Emissions from Electrical Power Generation, Excluding Grid Losses:

$$\frac{g\ NOX\ (as\ NO2)}{tonne\ Shredder\ Feed} = \frac{0.36\ Tonnes\ NOX\ (as\ NO2)}{Net\ GW\text{-}hr} \times \frac{28.8\ kW\text{-}hr}{tonne\ Shredder\ Feed} \times \frac{GW\text{-}hr}{10^6\ kW\text{-}hr} \times \frac{10^6\ g}{tonne}$$

$$= 10.4\ g/tonne\ Shredder\ Feed$$

l. PM Emissions from Shredder Air Emission Control Systems:

$$\frac{g\ PM}{tonne\ Shredder\ Feed} = \frac{g\ PM_{Shredder\ Fume\ Control\ System}}{tonne\ Shredder\ Feed} + \frac{g\ PM_{Material/Air\ Separation\ System}}{tonne\ Shredder\ Feed}$$

$$= \left[\left(\frac{g\ PM_{Shredder\ Fume\ Control\ System}}{sec} \Big/ \frac{X\ tonnes\ Shredder\ Feed}{hr}\right) \times \frac{3600\ sec}{hr}\right]$$

$$+ \left[\left(\frac{g\ PM_{Material/Air\ Separation\ System}}{sec} \Big/ \frac{Y\ tonnes\ Shredder\ Feed}{hr}\right) \times \frac{3600\ sec}{hr}\right]$$

$$= \left[\left(\frac{0.14\ g}{sec} \Big/ \frac{X\ tonnes\ Shredder\ Feed}{hr}\right) \times \frac{3600\ sec}{hr}\right]$$

$$+ \left[\left(\frac{0.56\ g}{sec} \Big/ \frac{Y\ tonnes\ Shredder\ Feed}{hr}\right) \times \frac{3600\ sechr}{hr}\right]$$

$$= 15.7\ g/tonne\ Shredder\ \ Feed$$

APPENDIX E Table 39 Part-types recovered from HSELVs and sold for reuse, including corresponding Hollander and Pinnacle part numbers and rates of recovery and reuse.

Table 39 Part-types recovered from HSELVs and sold for reuse, including corresponding Hollander and Pinnacle part numbers and rates of recovery and reuse

Hollander Part No.	Pinnacle Part Code	Part Type	kg per tonne HSELVs Processed	kg per tonne Total ELVs Processed
300	AA	ENGINE	102.29	13.54
	ZZ	COMPLETE VEHICLE	54.60	7.23
400	BA	TRANSMISSION	47.77	6.32
100	CA	FRONT END ASSEM.	38.56	5.10
120	DA+DB	L&R FRONT DOOR	19.04	2.52
560	WA	WHEEL	14.23	1.88
130	DC+DD	L&R REAR DOOR	11.95	1.58
510	TA+TB	L&R F KNEE	10.00	1.32
160	RD+RE	L&R QUARTER PANEL	9.81	1.30
435	QB	REAR AXLE ASSEMBLY	8.63	1.14
170	PB	LID/GATE	5.27	0.70
190	RA	REAR BUMPER	3.64	0.48
117	CD	HOOD	3.34	0.44
682	HA	COMPRESSOR	2.83	0.37
105	CB	FRONT BUMPER	2.78	0.37
551	SA	STEERING GEAR/BOX	1.89	0.25
412	BB	TRANSFER CASE	1.68	0.22
601	EA	ALTERNATOR	1.53	0.20
	PF	ENGINE CROSSMEMBER	1.33	0.18
515	TH+TI	L&R FRONT SPINDLE	1.20	0.16
447	BC+BD	L&R AXLE SHAFT	1.13	0.15
238	JD	COLUMN	1.12	0.15
110	CE+CF	L&R FENDER	1.08	0.14
527	TC+TD	L&R F STRUT	1.04	0.14
675	NA	RADIATOR	0.98	0.13
253	JB	R AIR BAG	0.98	0.13
109	CQ	RADIATOR SUPPORT	0.97	0.13
585	WC	TIRE	0.93	0.12
440	QC	CARRIER ASSEMBLY	0.90	0.12
114	LA+LB	L&R HEADLAMP	0.89	0.12
155	PA	BED/BOX	0.88	0.12
128	DK+DL	L&R DOOR MIRROR	0.84	0.11
553	SB	STEERING PUMP	0.82	0.11
476	QD	REAR DEAD AXLE (FWD)	0.81	0.11
604	EB	STARTER	0.70	0.09
500	PC	FRAME	0.66	0.09
150	RC	REAR CLIP	0.64	0.08
277	GC+GD	L&R F DOOR WINDOW	0.62	0.082
434	QA	FRONT AXLE ASSEMBLY	0.62	0.082

Hollander Part No.	Pinnacle Part Code	Part Type	kg per tonne HSELVs Processed	kg per tonne Total ELVs Processed
600	XA	BATTERY	0.60	0.079
545	WH	ANTI-LOCK BRAKE PART	0.59	0.077
166	LK+LL	L&R TAILLIGHT	0.54	0.072
512	TE+TF	L&R F LOWER CONTROL ARM	0.52	0.069
200	ID	COMPLETE INTERIOR	0.52	0.068
275	GB	BACK WINDOW	0.50	0.066
125	DM+DN	L&R F WND REGULATOR	0.45	0.060
638	EG	A/V EQUIPMENT	0.40	0.053
197	FK	FUEL TANK	0.37	0.049
253	JA	L AIR BAG	0.36	0.048
679	HB	CONDENSER	0.34	0.046
306	AB	CYLINDER HEAD	0.33	0.044
327	KA	EXHAUST MANIFOLD	0.32	0.043
201+202	IA	FRONT SEAT	0.32	0.043
590	EC	ENGINE CONTROL MODULE (I.E. BRAIN BOX)	0.32	0.042
288	GI	ROOF GLASS/SUNROOF/T	0.30	0.040
674	HC	ENGINE COOLING MOTOR	0.27	0.036
323	FL	FUEL PUMP	0.23	0.031
	PD	CAB CLIP	0.23	0.030
510	UA+UB	L&R R KNEE	0.18	0.024
620	EH	WIPER MOTOR FRONT	0.17	0.023
220	IC	3RD SEAT	0.17	0.022
610	EJ	COIL/COIL PACK	0.15	0.020
475	UG	COMPLETE REAR SUSPEN	0.15	0.020
524	TN	STABILIZER BAR	0.15	0.020
621	JM	WIPER TRANS.	0.15	0.019
431	OA	REAR DRIVE SHAFT	0.14	0.018
615	EE	HEATER MOTOR	0.14	0.018
278	GE+GF	L&R R DOOR WINDOW	0.13	0.018
284	GG+GH	L&R QUARTER WINDOW	0.13	0.017
430	OB	FRONT DRIVE SHAFT	0.13	0.017
152	RF	ROOF	0.11	0.015
154	PE	TRUCK CAB	0.11	0.015
215	IB	2ND SEAT (REAR SEAT)	0.10	0.014
606	AC	DISTRIBUTOR	0.10	0.013
	DE+DF	L&R ROCKER & POST	0.09	0.012
336	FB	AIR FLOW METER	0.081	0.011
102	CC	HEADER PANEL	0.059	0.0078
104	CG	GRILLE	0.056	0.0074
257	JF	SPEEDOMETER	0.052	0.0068

Hollander Part No.	Pinnacle Part Code	Part Type	kg per tonne HSELVs Processed	kg per tonne Total ELVs Processed
591	ED	CHASSIS CONTROL MODULE (I.E. BRAIN BOX)	0.050	0.0067
618	EI	WIPER MOTOR REAR	0.045	0.0060
250	JI	DASH ASSEMBLY	0.045	0.0060
309	AN	HARMONIC BALANCER	0.042	0.0056
	HE	HEAT/AC CONTROLER	0.039	0.0051
210	IE	SEAT BELT	0.035	0.0046
116	LC+LD	L&R FRONT LAMP	0.032	0.0043
518	PK	R LEAF SPRING	0.032	0.0042
135	DO+DP	L&R R WND REGULATOR	0.031	0.0041
241	IM	CONSOLE	0.029	0.0038
311	AF	OIL PAN	0.022	0.0029
527	UC+UD	L&R R STRUT	0.020	0.0027
326	AG	FAN CLUTCH	0.016	0.0022
321	AD	TURBOCHARGER	0.016	0.0021
270	GA	WINDSHIELD	0.015	0.0021
122	XT+XU	LH&RH RUNNING BOARD	0.013	0.0018
629	VA	COMBINATION SWITCH	0.012	0.0016
521	TO	FRONT TORSION BAR	0.010	0.0014
570	WB	WHEEL COVER	0.009	0.0012
511	TK+TL	L&R F UPPER CONTROL ARM	0.0091	0.0012
129	DR	DOOR HANDLE	0.0086	0.0011
319	FA	AIR CLEANER/BOX	0.0081	0.0011
328	KE	EXHAUST SYSTEM	0.0063	0.0008
540	WI	POWER BRAKE BOOSTER	0.0058	0.0008
633	VB	IGNITION W/ KEY	0.0054	0.0007
490	UM+UL	L&R REAR SPINDLE	0.0051	0.00068
335	KD	CATALYTIC CONVERTER	0.0049	0.00065
586	PP	TRAILER HITCH	0.0048	0.00064
536	WN+WO	L&R F CALIPER	0.0046	0.00062
169	RH	REAR SPOILER	0.0044	0.00058
	LM	FINISH PANEL - REAR	0.0041	0.00054
517	UI	REAR COIL SPRING	0.0039	0.00052
409	AE	FLYWHEEL	0.0031	0.00041
564	WL	JACK/TOOL KIT	0.0030	0.00039
538	UK	HUB	0.0029	0.00039
148	XV	LUGGAGE RACK	0.0028	0.00037
566	WK	SPARE TIRE/CARRIER	0.0026	0.00035
646	EN	FUSE BOX	0.0026	0.00034
343	AO	ENGINE MOUNT	0.0023	0.00030
260	IR	GLOVE BOX	0.0022	0.00030

Hollander Part No.	Pinnacle Part Code	Part Type	kg per tonne HSELVs Processed	kg per tonne Total ELVs Processed
522	UQ	AIR RIDE COMPRESSOR	0.0021	0.00028
370	FF	INJECTOR PUMP	0.0021	0.00027
505	UN	R REAR UPR CONT ARM	0.0020	0.00027
337	FD	THROTTLE BODY	0.0019	0.00025
206	II	HEADREST	0.0016	0.00021
	RN	CONV. LIFT MOTOR	0.0016	0.00021
	UP	REAR SWAY BAR	0.0013	0.00017
607	MK	BATTERY TRAY	0.0011	0.00015
541	WG	MASTER CYLINDER	0.0011	0.00014
267	JJ	INTERIOR MIRROR	0.0009	0.00012
	VI	PWR DR WIND SWITCH	0.0009	0.00012
676	HH	HEATER CORE	0.0008	0.00010
242	BH	SHIFTER	0.00074	0.00010
342	ME	MISC BRACKET	0.00074	0.00010
	IV	LID TRIM PANEL	0.00072	0.00010
322	FC	MISC FUEL INJ PART	0.00072	0.00010
627	JO	WASHER BOTTLE	0.00070	0.00009
205	IY+IZ	LH&RH R DOOR TRIM PANEL	0.00067	0.00009
	HL	A/C DRYER	0.00059	0.00008
266	IO	ARMREST	0.00058	0.00008
235	JL	STEERING WHEEL	0.00058	0.00008
534	WE	FRONT BRAKE	0.00054	0.00007
174+184	RQ	LID/GATE HINGE	0.00048	0.00006
268	IN	SUNVISOR	0.00045	0.00006
619	CH+CI	L&R HEADLIGHT MOTOR	0.00037	0.00005
671	NI	OVERFLOW BOTTLE	0.00032	0.00004
626	JN	WIPER ARM	0.00032	0.00004
204	IW+IX	LH&RH F DOOR TRIM PANEL	0.00027	0.00004
613	EM	HORN	0.00026	0.00003
	CK	HOOD LATCH	0.00013	0.00002
	IS	REAR TRIM	0.00006	0.00001
176	LN	3RD BRAKE LIGHT	0.00005	0.00001

APPENDIX F Table 40 Part-types recovered from LSELVs and sold for reuse, including rates of recovery and reuse.

Table 40 Part-types recovered from LSELVs and sold for reuse, including rates of recovery and reuse

	Part Type	kg per tonne LSELVs Processed	kg per tonne Total ELVs Processed
1	BATTERY	1.600	1.388
2	FRONT SEAT CAR	0.514	0.446
3	FRONT STRUT AND SPRING ASSY	0.461	0.400
4	DOOR - FRONT WITH DOOR MIRROR	0.297	0.257
5	LID/GATE- VAN/CAR	0.289	0.251
6	DOOR - FRONT W/O DOOR MIRROR	0.270	0.234
7	HOOD	0.265	0.230
8	DOOR - REAR	0.249	0.216
9	ROTOR - FLAT DISC	0.226	0.196
10	ENGINE ASSY.	0.214	0.186
11	MUFFLER	0.188	0.163
12	ENGINE ASSY - W/O ACCESSORIES	0.160	0.139
13	FRONT SEAT VAN	0.150	0.130
14	BENCH SEAT W/O SEATBELTS	0.121	0.105
15	TRANSMISSION - AUTOMATIC	0.111	0.096
16	REAR AXLE ASSY RWD OR 4W	0.103	0.089
17	REAR SEAT CAR	0.101	0.088
18	FENDER	0.099	0.086
19	RADIATOR	0.094	0.082
20	MUD GUARD -EACH	0.083	0.072
21	DOOR GLASS	0.079	0.069
22	TRANSMISSION - STANDARD	0.077	0.067
23	SLIDING DOOR	0.075	0.065
24	FRONT BUMPER - COMPLETE	0.073	0.063
25	FRONT BUMPER - COVER ONLY	0.072	0.062
26	TRUCK CAB	0.069	0.060
27	ALTERNATOR - DOMESTIC	0.068	0.059
28	BED/BOX	0.064	0.055
29	AXLE SHAFT (FWD)	0.062	0.054
30	RADIATOR SUPPORT	0.061	0.053
31	DOOR MIRROR - ELECTRIC	0.060	0.052
32	FRONT SPINDLE	0.059	0.051
33	CALIPER-FRONT	0.055	0.048
34	LID / GATE P/UP TRUCK	0.052	0.045
35	MUD GUARD - SET 4	0.052	0.045
36	HEADLAMP-EURO SMALL	0.048	0.042
37	DOOR-VAN-REARBARN	0.047	0.041
38	SPEAKER	0.046	0.040
39	COMPLETE INTERIOR	0.045	0.039
40	EXHAUST SYSTEM-COMP W/MUFFLER	0.045	0.039
41	A/C COMPRESSOR	0.044	0.038
42	ALL 4 DOORS MANUAL OR POWER	0.041	0.036
43	REAR SPOILER	0.041	0.036
44	FRONT AXLE ASSY RWD OR 4W	0.040	0.034
45	CYLINDER HEAD	0.039	0.034
46	WINDOW MOTOR W/REGULATOR	0.038	0.033
47	RADIO - CASSETTE	0.038	0.033

	Part Type	kg per tonne LSELVs Processed	kg per tonne Total ELVs Processed
48	REAR BUMPER - COMPLETE ASSY	0.038	0.033
49	POWER STEERING PUMP	0.038	0.033
50	JACK - COMPLETE	0.035	0.030
51	TRAILER HITCH-COMPLETE	0.034	0.029
52	TAILLIGHT ASSY. CAR	0.033	0.029
53	WHEEL COVER-CONDITION C*BLACK*	0.032	0.027
54	FRONT LOWER CONTROL ARM	0.031	0.027
55	REAR BRAKE DRUM - CAR	0.030	0.026
56	ALTERNATOR - IMPORT	0.030	0.026
57	SEAT BELT	0.029	0.025
58	QUARTER PANEL	0.029	0.025
59	HEADLAMP-EURO	0.028	0.024
60	EXHAUST MANIFOLD	0.027	0.024
61	CONSOLE-CENTRE	0.027	0.023
62	DASH ASSY	0.025	0.022
63	STARTER - DOMESTIC	0.025	0.022
64	FLOOR MATS - SET OF 4	0.023	0.020
65	BENCH SEAT W/ SEATBELTS	0.023	0.020
66	REAR BUMPER - COVER ONLY	0.023	0.020
67	HUB	0.023	0.020
68	SUNVISOR	0.023	0.020
69	TRUCK CAP	0.022	0.019
70	BACK WINDOW	0.022	0.019
71	ENGINE COOLING MOTOR	0.021	0.018
72	WINDOW REGULATOR	0.020	0.018
73	DOOR MIRROR - MANUAL REMOTE	0.020	0.018
74	STABILIZER BAR	0.020	0.018
75	FRONT BUMPER - RE-BAR ONLY	0.020	0.017
76	FENDER FLARES	0.020	0.017
77	STEERING COLUMN	0.019	0.017
78	DOOR MIRROR - BASIC CAR	0.019	0.016
79	REAR STRUT AND SPRING ASSEMBLY??	0.017	0.015
80	HEATER MOTOR	0.017	0.015
81	CORNERING LAMP	0.017	0.015
82	ANTI-LOCK BRAKE PART	0.017	0.015
83	FRONT COIL SPRING	0.017	0.015
84	WIPER MOTOR FRONT	0.016	0.014
85	QUARTER WINDOW	0.016	0.014
86	CARRI ER ASSY	0.016	0.014
87	CALIPER - FRONT W/ ANCHOR	0.015	0.013
88	ALL 4 DOORS PLUS HATCH	0.015	0.013
89	FLOOR MATS - EACH	0.015	0.013
90	WIRE HARNESS - SM (W/O RELAYS)	0.015	0.013
91	ROOF RACK	0.014	0.012
92	WIPERARM C/W BLADE	0.014	0.012
93	INNER FENDER LINER	0.014	0.012
94	JACK - INCOMPLETE	0.014	0.012
95	REAR BRAKE DRUM - TRUCK/VAN	0.014	0.012
96	STABILIZER LINK	0.013	0.011

	Part Type	kg per tonne LSELVs Processed	kg per tonne Total ELVs Processed
97	ENGINE BRAIN/BODY CONTROL MOD	0.013	0.011
98	FRONT STRUT - NO SPRING	0.013	0.011
99	HORN	0.013	0.011
100	POWER BRAKE BOOSTER	0.013	0.011
101	WIPER MOTOR W/ TRANSMISSION	0.012	0.010
102	WINDSHIELD	0.012	0.010
103	COWL	0.012	0.010
104	SEAT TRACK	0.012	0.010
105	TRIM PIECE - SMALL	0.011	0.010
106	CALIPER - REAR	0.011	0.010
107	INTAKE MANIFOLD	0.011	0.010
108	AXLE HOUSING	0.011	0.010
109	DOOR PANEL	0.011	0.010
110	STEERING GEAR BOX	0.011	0.009
111	EXHAUST PIPE - SM	0.011	0.009
112	BRAKE SHOES - SET OF 4	0.011	0.009
113	AIR BAG	0.011	0.009
114	A/C CONDENSER	0.011	0.009
115	BOX LINER	0.010	0.009
116	CALIPER ANCHOR	0.010	0.009
117	MASTER CYLINDER	0.010	0.009
118	COIL PACK	0.010	0.009
119	GLOVE BOX COMPLETE	0.0097	0.0084
120	TRIM PIECE-MED	0.0097	0.0084
121	TIRE	0.0094	0.0082
122	SPARE TIRE	0.0093	0.0080
123	RADIATOR W/ 2 FANS	0.0092	0.0080
124	DOOR TRIM PANEL - SMALL	0.0092	0.0080
125	STEERING WHEEL	0.0089	0.0077
126	TAILLIGHT ASSY. - VAN	0.0087	0.0076
127	HEADREST	0.0086	0.0075
128	HATCH STRUT/SHOCK - LARGE	0.0086	0.0075
129	WIPER TRANSMISSION-COMPLETE	0.0080	0.0069
130	FRONT SHOCK	0.0077	0.0067
131	STEERING GEAR, RAC & PINION	0.0077	0.0066
132	FUEL PUMP-IN TANK W/O S/UNIT	0.0076	0.0066
133	SUNROOF PANEL-GLASS	0.0076	0.0066
134	ENGINE CROSSMEMBER	0.0075	0.0065
135	HEADLINER / ROOF LINER	0.0074	0.0064
136	TRIM PIECE - LG	0.0073	0.0063
137	HEAT / AC CONTROLLER	0.0072	0.0062
138	ROTOR - BEARING STYLE - SM	0.0072	0.0062
139	HATCH STRUT/SHOCK - SMALL	0.0071	0.0062
140	BUG DEFLECTOR	0.0071	0.0061
141	STARTER - IMPORT	0.0069	0.0060
142	TRANSFER CASE	0.0069	0.0060
143	BRUSH GUARD	0.0067	0.0059
144	AIR FILTER	0.0067	0.0058
145	FILLER NECK	0.0066	0.0058

	Part Type	kg per tonne LSELVs Processed	kg per tonne Total ELVs Processed
146	COOLANT / OVERFLOW BOTTLE	0.0066	0.0057
147	DISTRIBUTOR - IMPORT	0.0066	0.0057
148	ROOF	0.0065	0.0056
149	WINDOW MOTOR (DOOR / TAILGATE)	0.0065	0.0056
150	HEADLIGHT DOOR	0.0064	0.0055
151	HEADLAMP - SEALED BEAM	0.0063	0.0055
152	TAPE PLAYER	0.0063	0.0055
153	WEATHER STRIP	0.0063	0.0055
154	CUP HOLDER	0.0063	0.0054
155	ROTOR - BEARING STYLE, MED	0.0062	0.0054
156	REAR DRIVE SHAFT	0.0062	0.0053
157	AXLE SHAFT - RWD	0.0062	0.0053
158	DOOR HANDLE - OUTSIDE	0.0062	0.0053
159	MISC ENGINE PARTS	0.0060	0.0052
160	RIM,STEEL	0.0059	0.0052
161	REAR DIFFERENTIAL	0.0059	0.0051
162	INJECTOR PUMP	0.0057	0.0049
163	TRIM PANEL EXTRA LARGE	0.0056	0.0049
164	BRAKE PADS - SET OF 4	0.0056	0.0049
165	DOOR MIRROR - TRUCK	0.0055	0.0048
166	CARPET	0.0055	0.0047
167	FUSE BOX	0.0055	0.0047
168	REAR BUMPER FILLER PANEL	0.0054	0.0047
169	RADIO CD PLAYER	0.0054	0.0047
170	WHEEL COVER - SET OF 4	0.0054	0.0047
171	SPEEDOMETER TRIM	0.0053	0.0046
172	REAR STRUT - NO SPRING	0.0053	0.0046
173	THROTTLE BODY	0.0053	0.0046
174	REAR BUMPER - REBAR ONLY	0.0053	0.0046
175	VENT WINDOW	0.0052	0.0046
176	DOOR MOULDING - SMALL	0.0052	0.0045
177	AIR CLEANER/ BOX	0.0052	0.0045
178	DISTRIBUTOR WIRES	0.0052	0.0045
179	AIR FLOW METER	0.0051	0.0045
180	ENGINE MOUNT - MEDIUM	0.0051	0.0044
181	DISTRIBUTOR - DOMESTIC	0.0051	0.0044
182	CYLINDER BLOCK	0.0050	0.0043
183	REAR SHOCKS	0.0050	0.0043
184	WASHER BOTTLE - W/O PUMP	0.0048	0.0042
185	SPARE TIRE COVER	0.0048	0.0041
186	COIL	0.0047	0.0041
187	FRONT DRIVE SHAFT	0.0047	0.0041
188	RADIO W/ CD & CASS.	0.0045	0.0039
189	TURBO/SUPER CHARGER	0.0045	0.0039
190	POWER MULTI SWITCH ASSY	0.0044	0.0038
191	EGR VALVE - ELECTRICAL TYPE	0.0042	0.0037
192	TRUNK CARPET	0.0042	0.0036
193	AIR CEANER / BOX	0.0042	0.0036
194	2 PIECE DRIVE SHAFT	0.0042	0.0036

	Part Type	kg per tonne LSELVs Processed	kg per tonne Total ELVs Processed
195	HEADER PANEL - BARE	0.0041	0.0036
196	DOOR HINGE	0.0040	0.0035
197	STEERING KNUCKLE	0.0040	0.0035
198	GRILLE - MEDIUM	0.0040	0.0035
199	WATER PUMP	0.0040	0.0034
200	DOOR LATCH ASSY.	0.0038	0.0033
201	GAS DOOR	0.0037	0.0033
202	RAD HOSE	0.0037	0.0032
203	WIRE HARNESS- MED (W/O RELAYS)	0.0036	0.0031
204	EXHAUST DOWNPIPE -W/FLEX	0.0035	0.0031
205	WIRE HARNESS- LG (W/O RELAYS)	0.0035	0.0030
206	DASH PAD	0.0035	0.0030
207	LEAF SPRING	0.0035	0.0030
208	ROTOR - BEARING STYLE - LG	0.0035	0.0030
209	CYLINDER HEAD COVER - ALUMINUM	0.0034	0.0030
210	VACUUM PUMP	0.0034	0.0030
211	REAR VIEW MIRROR	0.0034	0.0029
212	REAR SPINDLE	0.0034	0.0029
213	WIPER MOTOR REAR	0.0033	0.0029
214	COWL VENT PANEL	0.0032	0.0028
215	SPARE TIRE CARRIER - METAL	0.0032	0.0028
216	HEATER HOUSING	0.0032	0.0028
217	EXHAUST DOWNPIPE - W/O FLEX PIPE	0.0032	0.0027
218	SEAT BELT - FEMALE PIECE ONLY	0.0031	0.0027
219	AIR CLEANER/ BOX 1/2 ONLY	0.0031	0.0027
220	TRUNK LATCH	0.0031	0.0027
221	WIRE HARNESS - ENG. W/FUSE BOX	0.0031	0.0027
222	ROOF RACK-IND/LADDER RACK	0.0031	0.0027
223	TIE ROD END - INNER & OUTER	0.0031	0.0027
224	CARBURETOR	0.0030	0.0026
225	ENGINE MOUNT - COMPLETE	0.0029	0.0025
226	CHROME MOULDING - LARGE	0.0029	0.0025
227	TAIL PANEL LARGE	0.0029	0.0025
228	BELT TENSIONER - COMPLETE	0.0029	0.0025
229	PARCEL SHELF-COVER	0.0028	0.0024
230	REAR SWAY BAR	0.0028	0.0024
231	ARMREST - SMALL	0.0028	0.0024
232	AMPLIFIER	0.0028	0.0024
233	DOOR LATCH-WITH ACTUATOR	0.0028	0.0024
234	MISC BRACKET	0.0028	0.0024
235	AIR PUMP	0.0028	0.0024
236	DOG HOUSE - INSIDE VAN	0.0027	0.0024
237	BRAKE LINE	0.0027	0.0024
238	MOULDING	0.0027	0.0024
239	ALTERNATOR BRACKET	0.0027	0.0024
240	WASHER BOTTLE-WITH PUMP	0.0027	0.0024
241	ENGINE MOUNT - SMALL	0.0027	0.0024
242	RUNNING BOARDS - PER SIDE	0.0027	0.0023
243	ASHTRAY	0.0027	0.0023

	Part Type	kg per tonne LSELVs Processed	kg per tonne Total ELVs Processed
244	TIMING GEARS	0.0027	0.0023
245	FRONT UPPER CONTROL ARM	0.0027	0.0023
246	TAIL PANEL SMALL	0.0026	0.0023
247	DISTRIBUTOR CAP W/ WIRES	0.0026	0.0023
248	FRONT STRUT - AIR SUSPENSION	0.0026	0.0023
249	GAS CAP	0.0026	0.0023
250	DOOR HANDLE - INSIDE	0.0026	0.0023
251	EXHAUST PIPE - MED	0.0026	0.0022
252	BACK WINDOW BARN DOOR - VAN	0.0026	0.0022
253	SUNROOF PANEL - CARDBOARD	0.0026	0.0022
254	HEADLIGHT SWITCH	0.0025	0.0022
255	DOOR MIRROR SAIL TYPE VAN/SUV	0.0025	0.0022
256	A/C EVAPORATOR	0.0025	0.0021
257	HOOD LATCH	0.0024	0.0021
258	BRAKE BACKING PLATE - W/CYL	0.0024	0.0021
259	FAN CLUTCH COMPLETE	0.0024	0.0021
260	LADDER RACK	0.0024	0.0020
261	DOOR TRIM PANEL - MEDIUM	0.0024	0.0020
262	GLOVE BOX - LID ONLY	0.0024	0.0020
263	VACUUM PIECES-LARGE	0.0023	0.0020
264	FAN CLUTCH - COMPLETE	0.0023	0.0020
265	FOG LAMP	0.0023	0.0020
266	ELECTRIC SEAT MOTOR	0.0023	0.0020
267	CATALYTIC CONVERTER	0.0022	0.0019
268	TRAILER HITCH TONGUE & BALL	0.0022	0.0019
269	TAILLIGHT - P/UP TRUCK	0.0022	0.0019
270	HEATER CORE	0.0022	0.0019
271	PARK BRAKE ASSY.	0.0021	0.0018
272	HARMONIC BALANCER	0.0021	0.0018
273	DASH RADIO TRIM	0.0020	0.0018
274	GRILLE - TRUCK/VAN	0.0020	0.0017
275	FLEX PLATE	0.0020	0.0017
276	OIL PAN	0.0020	0.0017
277	CD CHANGER	0.0020	0.0017
278	SUB FRAME	0.0019	0.0017
279	INTERIOR 1/4 PANEL MOULDING-LG	0.0019	0.0017
280	REAR STRUT - AIR SUSPENSION	0.0019	0.0017
281	ROCKER AND POST	0.0019	0.0017
282	SPEEDOMETER-ANALOG	0.0019	0.0016
283	LIC. PLATE HOLDER	0.0019	0.0016
284	A/C HOSES/LINES - ONE PIECE	0.0019	0.0016
285	WEATHER STRIP - SM. PIECES	0.0018	0.0016
286	STEERING COLUMN W/ AIR BAG	0.0018	0.0016
287	SEAT COVER	0.0018	0.0016
288	AIR IDLER CONTROL VALVE	0.0018	0.0015
289	WINDSHIELD FRAME	0.0018	0.0015
290	FUEL SENDING UNIT	0.0018	0.0015
291	CANISTER/CHARCOAL/VACUUM LARGE	0.0018	0.0015
292	MISC SWITCH	0.0018	0.0015

	Part Type	kg per tonne LSELVs Processed	kg per tonne Total ELVs Processed
293	ARMREST - LARGE	0.0018	0.0015
294	CONSOLE CENTRE - LID ONLY	0.0018	0.0015
295	ROTOR -TRUCK AND F/S VAN	0.0017	0.0015
296	TRUNK HINGE	0.0017	0.0015
297	GRILLE - SMALL	0.0017	0.0015
298	CYLINDER HEAD COVER - METAL	0.0017	0.0015
299	WIPER BLADE (EACH)	0.0017	0.0015
300	CANISTER/CHARCOAL/VACUUM SM	0.0017	0.0015
301	MISC PULLEY	0.0017	0.0015
302	ROCKER MOULDING - MEDIUM	0.0017	0.0014
303	CRANKSHAFT	0.0016	0.0014
304	CARGO NET	0.0016	0.0014
305	DRIVER INFORMATION CENTRE	0.0016	0.0014
306	WHEEL CYLINDER	0.0016	0.0014
307	SUNROOF PANEL-METAL	0.0015	0.0013
308	PARCEL SHELF-ROLL OUT TYPE	0.0015	0.0013
309	CHROME MOULDING - MEDIUM	0.0015	0.0013
310	PARK BRAKE HANDLE/PEDAL-ONLY	0.0015	0.0013
311	EGR VALVE -VACUUM TYPE	0.0015	0.0013
312	GRILLE - CAR - LARGE	0.0015	0.0013
313	CONSOLE-OVERHEAD	0.0014	0.0013
314	BRAKE PEDAL	0.0014	0.0013
315	REAR LOWER CONTROL ARM	0.0014	0.0013
316	SLIDING DOOR POWER ASSY.	0.0014	0.0013
317	JACK - HANDLE ONLY	0.0014	0.0012
318	REAR COIL SPRING	0.0014	0.0012
319	COIL PACK - MODULE ONLY	0.0014	0.0012
320	EXHAUST PIPE - LG	0.0014	0.0012
321	CENTER CAP	0.0014	0.0012
322	MISC MODULE	0.0014	0.0012
323	SHIFTER - BASIC	0.0014	0.0012
324	TIE ROD END	0.0014	0.0012
325	INTERIOR 1/4 PANEL MOULDING-XL	0.0013	0.0012
326	ANTENNA - POWER	0.0013	0.0011
327	BRAKE CABLE	0.0013	0.0011
328	CAM SHAFT	0.0013	0.0011
329	TIMING COVER	0.0013	0.0011
330	SLIDING DOOR HINGE	0.0013	0.0011
331	A/C DRYER	0.0013	0.0011
332	DOOR MIRROR - MIRROR ONLY	0.0013	0.0011
333	INTERCOOLER	0.0012	0.0011
334	FRONT BUMPER FILLER PANEL	0.0012	0.0010
335	TORQUE CONVERTOR	0.0012	0.0010
336	FRONT VALANCE-LW PLSTC GRAVL	0.0012	0.0010
337	BRAKE BACKING PLATE - W/O CYL	0.0012	0.0010
338	HOOD HINGE	0.0012	0.0010
339	WINDSHIELD MOULDINGS	0.0011	0.0010
340	SHIFTER - COMPLETE	0.0011	0.0010
341	IGNITION SWITCH	0.0011	0.0010

	Part Type	kg per tonne LSELVs Processed	kg per tonne Total ELVs Processed
342	FAN BLADE	0.0011	0.0010
343	VACUUM PIECES- SMALL	0.0011	0.0009
344	SPEEDOMETER - HEAD ONLY	0.0010	0.0009
345	TRANSMISSION OIL COOLER	0.0010	0.0009
346	BUMPERETTE	0.0010	0.0009
347	ANTENNA - MANUAL W/O WIRE	0.0010	0.0009
348	INJECTOR RAIL W/ INJECTORS 6CY	0.0010	0.0009
349	DOOR MOULDING - MED	0.00099	0.00086
350	POWER WINDOW SWITCH - COMPLETE	0.00098	0.00085
351	DOOR MOULDING - LG	0.00098	0.00085
352	TRUNK LID	0.00096	0.00084
353	RADIO - AM/FM ONLY	0.00096	0.00084
354	POWER DOOR LOCK ACTUATOR	0.00096	0.00083
355	BRAKE PROPORTION VALVE	0.00094	0.00082
356	SPARK PLUG WIRE	0.00094	0.00081
357	HOOD RELEASE - W/CABLE	0.00091	0.00079
358	ROCKER MOULDING - SMALL	0.00090	0.00078
359	STARTER SOLENOID	0.00089	0.00077
360	AIR INDUCTION HOSE-SMALL	0.00085	0.00074
361	ENGINE MOUNT - LARGE	0.00085	0.00074
362	SHIFTER CABLE	0.00084	0.00073
363	COMBINATION SWITCH	0.00084	0.00072
364	WINDOW REGULATOR - PLSTC TRACK	0.00083	0.00072
365	TAIL PANEL W/INNER TAIL LIGHTS	0.00083	0.00072
366	HEAT / AC CONTROLLER - DIGITAL	0.00082	0.00071
367	FAN SHROUD	0.00081	0.00071
368	ENGINE PULLEY - SMALL	0.00079	0.00068
369	SEAT BELT MOTOR	0.00076	0.00066
370	ROCKER MOULDING - LARGE	0.00075	0.00065
371	FUEL DIST. UNIT	0.00073	0.00064
372	TRANSMISSION MOUNT - MEDIUM	0.00073	0.00063
373	TRANSMISSION MOUNT - SMALL	0.00073	0.00063
374	BATTERY TRAY	0.00073	0.00063
375	VENT GLASS FRAME	0.00072	0.00063
376	MARKER LIGHT - SM	0.00072	0.00062
377	MULTI FUNCTION RELAY BOX	0.00071	0.00062
378	BRAKE SHOES - EACH	0.00071	0.00062
379	ANTENNA - MANUAL W/ WIRE	0.00071	0.00061
380	WIRE HARNESS - ENG. INCOMPLETE	0.00069	0.00060
381	A/C HOSES / LINES	0.00069	0.00060
382	3RD BRAKE LIGHT	0.00067	0.00059
383	OIL COOLER	0.00067	0.00058
384	BELT	0.00067	0.00058
385	VENT - DASH	0.00067	0.00058
386	FUEL PUMP - ELEC EXTERNAL	0.00067	0.00058
387	WASHER BOTTLE - 2 PUMPS	0.00066	0.00057
388	WIPER TRNSMISSION - ARM ONLY	0.00066	0.00057
389	FAN CLUTCH - W/O FAN	0.00065	0.00057
390	FAN CLUTCH W/O FAN	0.00065	0.00057

	Part Type	kg per tonne LSELVs Processed	kg per tonne Total ELVs Processed
391	TAILLIGHT ASSY. SUV	0.00065	0.00056
392	CENTRE LINK - COMPLETE	0.00064	0.00056
393	SHIFTER BOOT	0.00064	0.00056
394	WIPER SWITCH	0.00064	0.00056
395	AIR RIDE COMPRESSOR	0.00064	0.00055
396	HOOD RELEASE - W/O CABLE	0.00063	0.00055
397	BUMPER SHOCK	0.00062	0.00054
398	FRONT BUMPER - IMPACT STRIP	0.00062	0.00054
399	POWER STEERING RESERVOIR	0.00061	0.00053
400	RELAY LARGE	0.00061	0.00053
401	QUARTER WINDOW MOTOR	0.00060	0.00052
402	WASHER PUMP	0.00060	0.00052
403	CHROME MOULDING - SMALL	0.00060	0.00052
404	GRILL-XL WITH BEZELS	0.00059	0.00051
405	POWER WINDOW SWITCH - SINGLE	0.00059	0.00051
406	HOOD SCOOP	0.00058	0.00051
407	ENGINE PULLEY - LARGE	0.00057	0.00050
408	STEERING COLUMN COVER	0.00056	0.00049
409	INTERIOR DOME LIGHT	0.00056	0.00049
410	MISC PULLEY - LARGE	0.00056	0.00048
411	CRUISE CONTROL UNIT	0.00054	0.00047
412	ENGINE PULLEY - MEDIUM	0.00054	0.00047
413	DISTRIBUTOR MODULE	0.00054	0.00047
414	FUEL INJECTOR EACH ONLY	0.00053	0.00046
415	A/C HOSES / LINES - COMPLETE	0.00052	0.00046
416	FRONT VALANCE - SKIRT STYLE	0.00052	0.00046
417	FUEL PUMP-IN TANK W/SEND/UNIT	0.00052	0.00045
418	HEATER SWITCH	0.00052	0.00045
419	SUNROOF - COMPLETE W/O MOTOR	0.00052	0.00045
420	IGNITION IGNITOR	0.00051	0.00044
421	INJECTOR RAILS W/INJECTORS 4CY (4 Clylinder)	0.00050	0.00044
422	SUNROOF MOTOR	0.00048	0.00042
423	PISTON	0.00048	0.00042
424	BUSHING	0.00048	0.00042
425	POWER WINDOW SWITCH 2 WAY	0.00048	0.00042
426	TEMPERATURE SENSOR	0.00048	0.00041
427	A/C ACCUMULATOR	0.00047	0.00041
428	DIMMER SWITCH	0.00046	0.00040
429	POWER DOOR LOCK SWITCH	0.00046	0.00040
430	BRAKE PADS - EACH	0.00046	0.00040
431	HOOD PROP	0.00044	0.00039
432	MARKER LIGHT - MED	0.00044	0.00038
433	INJECTOR RAIL - W/O INJECTORS	0.00044	0.00038
434	HEADLIGHT POTS	0.00043	0.00037
435	SPEAKER COVER	0.00042	0.00036
436	THROTTLE / ACCELERATOR CABLE	0.00042	0.00036
437	ASHTRAY - SMALL INSERTS	0.00042	0.00036
438	HEADER PANEL - (EURO STYLE) W	0.00041	0.00036
439	OXYGEN SENSOR	0.00041	0.00036

	Part Type	kg per tonne LSELVs Processed	kg per tonne Total ELVs Processed
440	CLUTCH MASTER CYLINDER	0.00041	0.00035
441	INTERIOR 1/4 PANEL MOULDING-MD	0.00040	0.00035
442	IDLER PULLEY	0.00039	0.00034
443	REAR BUMPER END	0.00039	0.00034
444	GRAB HANDLES	0.00037	0.00032
445	HOOD RELEASE CABLE	0.00037	0.00032
446	CLUTCH - COMPLETE PEDAL ASSY	0.00037	0.00032
447	EXHAUST HEAT SHIELD	0.00036	0.00032
448	SPARE TIRE CARRIER - CABLE	0.00034	0.00030
449	HEADLIGHT MOTOR	0.00034	0.00030
450	MISC VENTS - SINGLE	0.00034	0.00030
451	POWER STEERING LINES	0.00034	0.00029
452	FUSE PANEL COVER	0.00033	0.00029
453	SPEED SENSOR	0.00033	0.00029
454	INTERIOR MIRROR	0.00033	0.00029
455	GRILLE - CAR - XL	0.00032	0.00028
456	DRAG LINK	0.00032	0.00028
457	HOOD INSULATION	0.00032	0.00028
458	CLUTCH - PEDAL ONLY	0.00031	0.00027
459	REAR UPPER CONTROL ARM	0.00031	0.00027
460	ABS BRAKE SENSOR	0.00031	0.00027
461	CARBURETOR SPACER	0.00031	0.00027
462	MISC PULLEY - SMALL	0.00031	0.00026
463	SPEEDOMETER PLASTIC COVER	0.00030	0.00026
464	FRONT BUMPER GUARD	0.00030	0.00026
465	THERMOSTAT HOUSING - SMALL	0.00030	0.00026
466	SLAVE CYLINDER	0.00028	0.00025
467	REAR DIFFERENTIAL COVER	0.00028	0.00024
468	HEAT RESISTOR	0.00028	0.00024
469	WINDOW CRANK - HANDLE/WINDER	0.00027	0.00023
470	HAZARD SWITCH	0.00027	0.00023
471	MISC CABLE	0.00027	0.00023
472	TAILLIGHT LENS ONLY	0.00026	0.00023
473	DISTRIBUTOR PICK-UP COIL	0.00026	0.00022
474	ENGINE PULLEY - COMPLETE	0.00026	0.00022
475	CLUTCH CABLE	0.00026	0.00022
476	MISC PULLEY - MEDIUM	0.00026	0.00022
477	PITMAN ARM	0.00025	0.00022
478	AIR BAG - CLOCK SPRING	0.00025	0.00022
479	RADIATOR FAN	0.00025	0.00022
480	A/C HOSES/LINES - SMALL	0.00024	0.00021
481	POWER SEAT SWITCH - SINGLE (single toggle)	0.00024	0.00020
482	IDLE SPEED MOTOR	0.00024	0.00020
483	EXTERIOR MOULDING - MED	0.00024	0.00020
484	POWER STEERING BRACKET	0.00023	0.00020
485	A/C CLUTCH	0.00022	0.00019
486	FUEL FILTER	0.00022	0.00019
487	DIP STICK	0.00021	0.00019
488	STEERING WHEEL HORN COVER	0.00021	0.00018

	Part Type	kg per tonne LSELVs Processed	kg per tonne Total ELVs Processed
489	CYLINDER HEAD COVER - PLASTIC	0.00021	0.00018
490	HEADER PANEL - (SEALED BEAM) W	0.00021	0.00018
491	WHEEL TRIM RING	0.00020	0.00018
492	A/C COMPRESSOR BRACKET	0.00019	0.00017
493	POWER STEERING HOSE	0.00019	0.00017
494	CLOTH SEAT COVER	0.00019	0.00017
495	EXTERIOR MOULDING - LG	0.00019	0.00016
496	HEATER VALVE	0.00019	0.00016
497	FRONT LEATHER SEAT COVER	0.00018	0.00016
498	FRONT BUMPER END - XS	0.00018	0.00016
499	AXLE SHAFT BOOT	0.00018	0.00015
500	SERPENTINE BELT	0.00018	0.00015
501	BLOWER MOTOR	0.00017	0.00015
502	OIL FILTER	0.00017	0.00015
503	THERMOSTAT HOUSING - LARGE	0.00017	0.00014
504	SHIFT SELECTOR COVER	0.00017	0.00014
505	DOOR PANEL - W/ PWR MULTI SWTC	0.00017	0.00014
506	AIR INDUCTION HOSE-MEDIUM	0.00016	0.00014
507	POWER STEERING COOLER	0.00016	0.00014
508	RADIATOR CAP	0.00016	0.00014
509	MARKER LIGHT - LG	0.00016	0.00014
510	OIL PUMP	0.00015	0.00013
511	THROTTLE POSITION SENSOR	0.00015	0.00013
512	LID/GATE HINGE	0.00015	0.00013
513	THERMOSTAT HOUSING - MEDIUM	0.00014	0.00012
514	IGNITION ASSY	0.00014	0.00012
515	SHIFTER KNOB	0.00014	0.00012
516	DEFROST SWITCH	0.00014	0.00012
517	CLUTCH DISC	0.00013	0.00012
518	INTERIOR 1/4 PANEL MOULDING SM	0.00013	0.00012
519	DOOR LOCK CYLINDERS	0.00013	0.00012
520	TRUNK LOCK MECHANISM	0.00013	0.00011
521	TRUNK RELEASE/CABLE	0.00013	0.00011
522	ELECTRICAL RELAY	0.00013	0.00011
523	IDLER ARM	0.00013	0.00011
524	DISTRIBUTOR CAP	0.00012	0.00011
525	EGR TUBE	0.00012	0.00011
526	COOLANT LINES - SM	0.00012	0.00010
527	ROCKER ARM	0.00011	0.00009
528	ENGINE OIL COOLER	0.00010	0.00009
529	INTERMEDIATE SHAFT	0.00010	0.00009
530	COOLING MOTOR SHROUD	0.00010	0.00009
531	BUMPER BRACKET	0.00010	0.00009
532	WIPER PIVOT	0.00010	0.00009
533	OIL PRESSURE SWITCH	0.00010	0.00008
534	POWER SEAT SWITCH - DOUBLE (double toggle)	0.00010	0.00008
535	COOLANT LINES - MED	0.000094	0.000081
536	SPARK PLUG	0.000091	0.000079
537	GAS PEDAL	0.000091	0.000079

	Part Type	kg per tonne LSELVs Processed	kg per tonne Total ELVs Processed
538	AIR BAG SENSOR	0.000091	0.000079
539	OIL FILTER HOUSING	0.000090	0.000078
540	SIGNAL SWITCH - W/ WIRE	0.000087	0.000076
541	REAR SEAT LATCH (FOLD DOWN)	0.000081	0.000070
542	MOUNT-SM	0.000080	0.000070
543	FUEL PUMP-MECHANICAL	0.000077	0.000067
544	CPS - CAM POSITION SENSOR	0.000073	0.000064
545	SHIFTER ARM (COLUMN STYLE)	0.000073	0.000063
546	AIR INDUCTION HOSE-LARGE	0.000072	0.000062
547	HOOD SHOCK / STRUT	0.000071	0.000061
548	FUEL PRESSURE REGULATOR	0.000070	0.000061
549	RELAYS SMALL	0.000070	0.000061
550	GAS DOOR RELEASE CABLE	0.000066	0.000057
551	TRUNK LOCK CYLINDER	0.000065	0.000057
552	NEUTRAL SAFETY SWITCH	0.000064	0.000055
553	ELECTRICAL CONNECTORS	0.000063	0.000055
554	SPIDER GEARS	0.000063	0.000054
555	CIGARETTE L TR / POWER SUPPLY	0.000055	0.000048
556	OIL FILLER CAP	0.000053	0.000046
557	WHEEL COVER-CONDITION A*RED	0.000052	0.000045
558	WHEEL COVER-CONDITIO B*YELLOW*	0.000052	0.000045
559	DOOR HANDLE - TOP STYLE	0.000051	0.000044
560	PARKING LAMP	0.000050	0.000044
561	BATTERY HOLD DOWN	0.000050	0.000043
562	GLOVE BOX - LATCH ONLY	0.000048	0.000042
563	TIMING BELT	0.000048	0.000042
564	COOLANT LINES - LG	0.000047	0.000041
565	EXTERIOR MOULDING - SMALL 310A	0.000047	0.000041
566	BRAKE RESERVOIR	0.000046	0.000040
567	POWER MIRROR SWITCH	0.000042	0.000036
568	MARKER LIGHT- LENS ONLY	0.000041	0.000036
569	LICENSE LAMP ASSY.	0.000036	0.000032
570	FLASHER / HAZARD RELAY	0.000034	0.000030
571	HEATER MOTOR - FAN ONLY	0.000033	0.000029
572	MISC ORNAMENTS/EMBLEMS LARGE	0.000033	0.000029
573	QUARTER EXTENSION	0.000032	0.000028
574	BATTERY TERMINAL CABLE	0.000031	0.000027
575	A/C COOLING MODULE	0.000029	0.000025
576	MISC ORNAMENTS /EMBLEMS	0.000027	0.000023
577	HEADLAMP BULB	0.000027	0.000023
578	FUEL LINES - LARGE	0.000023	0.000020
579	BUZZER 1 DOOR CHIMER	0.000023	0.000020
580	FRONT SPOILER	0.000023	0.000020
581	A/C HOSES / LINES - MEDIUM	0.000020	0.000017
582	MOUNT - XS	0.000019	0.000016
583	DISTRIBUTOR IGNITION ROTOR	0.000015	0.000013
584	HEADLIGHT RELAY	0.000015	0.000013
585	TRANSMISSION DIP STICK	0.000014	0.000012
586	POWER STEERING CAP	0.000014	0.000012

	Part Type	kg per tonne LSELVs Processed	kg per tonne Total ELVs Processed
587	FUEL LINES - SMALL	0.000014	0.000012
588	MASTER CYLINDER COVER	0.000012	0.000010
589	LID PULL DOWN COMPLETE	0.000011	0.000010
590	BACK UP LAMP	0.000011	0.000009
591	FUEL PUMP RELAY	0.000010	0.000008
592	CRUISE CONTROL	0.0000089	0.0000077
593	HEATER A/C LINKAGE CABLE	0.0000067	0.0000058
594	STEERING GEAR BOOT	0.0000054	0.0000047
595	PCV VALVE	0.0000038	0.0000033
596	MISC FUEL INJECTION PART	0.0000033	0.0000029
597	BRAKE FLUID LEVEL SENSOR	0.0000008	0.0000007
598	SPEAKER WIRE	0.0000008	0.0000007

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