PE INTERNATIONAL
SUSTAINABILITY PERFORMANCE

UPDATE TO THE ALUMINUM CAN LCA STUDY

A Technical Memorandum prepared by PE INTERNATIONAL for the Aluminum Association
December 11, 2014

OVERVIEW

This technical memorandum describes the update to the 2010 *Life Cycle Impact Assessment of Aluminum Beverage Cans* report, prepared by PE Americas for the Aluminum Association. Since completion the of the 2010 study, the Aluminum Association has collected new data on aluminum and beverage can production, thus providing an impetus to update the results from the 2010 study.

This memorandum is intended to supplement the 2010 study by providing updated information. The 2010 study was a comprehensive LCA that included detailed information on the data, methods, and assumptions for both aluminum production and beverage can production. The general methods used in this update are consistent with the 2010 study and are thus not documented here. The data for primary and secondary aluminum production has been updated to be consistent with the information reported in *The Environmental Footprint of Semi-Finished Aluminum Products in North America*, published in December 2013 by the Aluminum Association. Please refer to these two studies for additional technical details related to aluminum production and beverage can production.

DATA

The data for this update comes from the 2013 AA study, the GaBi 2013 databases, and primary data collected for this update. The data for UBC scrap processing was not updated and was taken from the 2010 study. Table 1 presents the key datasets and sources.

Table 1. LCI data sources

Data	Source
Primary ingot	2013 AA study
Secondary ingot	2013 AA study
UBC scrap processing	2010 AA study
Hot rolling	2013 AA study
Cold rolling	2013 AA study
Can manufacturing	primary data (2012)
Landfill	GaBi 2013 databases
Transportation	GaBi 2013 databases

Primary data regarding can mass, recycling rate, and recycled content are as follows:

- Average can weight of 13.04 kg per 1000 2-piece (2 PC) cans in 2012[1]
- The U.S. consumer UBC recycling rate in the year 2012 is 54.6%[2,3]
- The recycled content of the beverage can in the U.S. in 2012 is 70%[4].

The can manufacturing process for a 2-piece can (lid and body) was updated for this study. The Aluminum Association and the aluminum industry are committed to a complete and transparent data collection process that complies with the internationally-recognized LCA methodology. In order to meet this commitment, the Aluminum Association, through the assistance of the Can Manufacturers Institute, surveyed all major can sheet producers and can manufacturers (four total companies). According to the Aluminum Association, the survey captured 94% of can sheet making and 99% of the can manufacturing in the United States. The primary data collected included raw material inputs (e.g., aluminum scrap, primary ingot), energy inputs, emissions to air and water, waste generation, scrap generation, and valuable product output. This data was used by PE INTERNATIONAL to create the LCA model as described in the *Modeling* section of this memorandum. The survey forms are shown in in the Appendix in Figures 10 and 11.

While the survey captured most of the can manufacturing in the United States, it should be noted that reporting data for the study was voluntary. Effort was made by the Aluminum Association to ensure that survey questions were well defined and support was provided for survey respondents. Follow-up verification for the primary data was carried out by the Aluminum Association to assure the quality of the information.

Aluminum can sheet manufacturing processes are similar between companies, but differences exist in the tracking from inputs through multiple product lines and the tracking of "run-around" scrap that crosses facility boundaries. The industry addressed material tracking reporting issues on a case-by-case basis to achieve the best quality of data possible through voluntary reporting. Similarly, standardized definitions for process inputs led to some differences in the treatment of materials in integrated production sites and disaggregated production chains. Finally, individual company methods to calculate

1 Data survey was conducted by the Can Manufacturers Institute and the Aluminum Association. Data survey is conducted annually.

2 US EPA, Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures for 2012. EPA, 2013. Available online at: http://www.epa.gov/osw/nonhaz/municipal/pubs/2012_msw_fs.pdf. This rate captures the collection rate of the cans; efficiency of the recycling process is captured elsewhere in the LCA model.

3 An alternative recycling rate, published by the Aluminum Industry, is based on the industry recycling rate and includes imported UBCs, and is thus not appropriate for the LCA model (reference: http://aluminum.org/news/aluminum-can-continues-leadership-sustainable-packaging-most-recycled-beverage-container). A consumer recycling rate is currently not available from the Aluminum Association. For this reason, the EPA rate of 54.6% was used for the LCA model.

4 Recycled content data was collected and aggregated by the Aluminum Association through direct surveys to can sheet manufacturers. Calculation of the content excluded the "run-around" scrap generated during the can sheet manufacturing process.

process loss (melt loss/scrap cleaning) may vary, leading to slightly inconsistent values for waste during the production process.

The raw LCI data was provided to PE INTERNATIONAL and modeled in the GaBi software, which involved mapping the input and output data to flows and process in the GaBi database. Table 2 presents the aggregated LCI data as integrated into GaBi.

Table 2. Inputs and outputs for the can manufacturing process

Inputs	**Value**	**Units**
Aluminum sheet [Metals]	15.5	Kg
Coatings (can) [Paints]	1.04	Kg
Electricity [Electric power]	109	MJ
Inks (can) [Paints]	0.0328	Kg
Lubricating oil [Operating materials]	0.0394	Kg
Thermal energy (MJ) [Thermal energy]	67.5	MJ
Water (tap water) [Operating materials]	76.0	kg
Outputs		
2-piece can [Metals]	1000	pcs.
Aluminum scrap [Waste for recovery]	2.42	kg
Dust (PM_{10}) [Particles to air]	0.000207	kg
Hazardous waste for incineration [Hazardous waste for disposal]	0.000752	kg
Nitrogen dioxide [Inorganic emissions to air]	0.00274	kg
Nitrous oxide (laughing gas) [Inorganic emissions to air]	0.000137	kg
Sludge [Hazardous waste]	0.174	kg
Sludge (from processing) [Waste for recovery]	0.02631	kg
Sulfur dioxide [Inorganic emissions to air]	1.63E-05	kg
Total waste for incineration [Waste for disposal]	0.225	kg
NMVOC (unspecified) [Organic emissions to air (group VOC)]	0.0648	kg
Waste (incineration) [Waste for disposal]	0.0497	kg
Waste (landfill) [Waste for disposal]	0.0440	kg
Waste (recycling) [Waste for recovery]	0.130	kg
Waste water [Other emissions to fresh water]	53.4	kg
Water vapor [Inorganic emissions to air]	22.6	kg

MODELING

The aluminum can profile was modeled using a cradle-to-grave system boundary (excluding the use phase) in the GaBi 6.3 LCA software package. The use phase was not included due to lack of data and lack of relevance for the purpose of this study. If included, the use phase would capture impacts associated with transportation, storage, refrigeration, amongst others. Two recycling allocation scenarios were modeled: avoided burden and recycled content.

Avoided Burden Scenario

Under the avoided burden scenario, secondary ingot that is produced from aluminum scraps is credited the environmental burden of an equivalent amount of virgin aluminum. This is generally done by first satisfying any input scrap demands (i.e., recycled content), and then putting the remaining net scrap through a recycling process until it is re-processed into an aluminum ingot. The end-of-life recycling rate is the key factor in this approach. The recycled content is addressed by satisfying the scrap demand and will alter the cradle-to-gate burdens, but does not affect the overall life cycle results.

The GaBi model for the avoided burden scenario is shown in Figure 1. When reviewing the figure, note that the negative sign of the flow input into the *Sent to recycling* process is due to the fact that additional scrap is needed as input into the system in order to satisfy the total scrap demand. Thus, scrap is actually sent from an external scrap supply (1.5 kilograms) into the aluminum can system, which adds additional primary burden to the product system. This is appropriate when the recycling rate is lower than the recycled content for a given system, as is the case with the modeled aluminum can system.

The model assumes closed-loop recycling in the aluminum can system. In reality, some of the scrap inputs and outputs are associated with other aluminum product systems. The influence of this assumption on the results are expected to be small and will only affect the scrap preparation process.

Recycled Content Scenario

Under the recycled content scenario, the recycled content (scrap) that enters the system is considered free of any primary environmental burden. Yet, inbound transportation as well as any processing and remelting of scrap is included within the system boundaries for recycled content. At the end-of-life, the system boundary is drawn at the point of scrap generation, with the recycling burden and credit for used beverage cans sent to recycling being excluded. The recycled content is the key parameter in recycled content approach; the end-of-life recycling rate has little effect on the results. The GaBi model for the recycled content scenario is shown in Figure 2; see notes in the *Avoided Burden Scenario* section regarding the negative flow to recycling and the source of scrap.

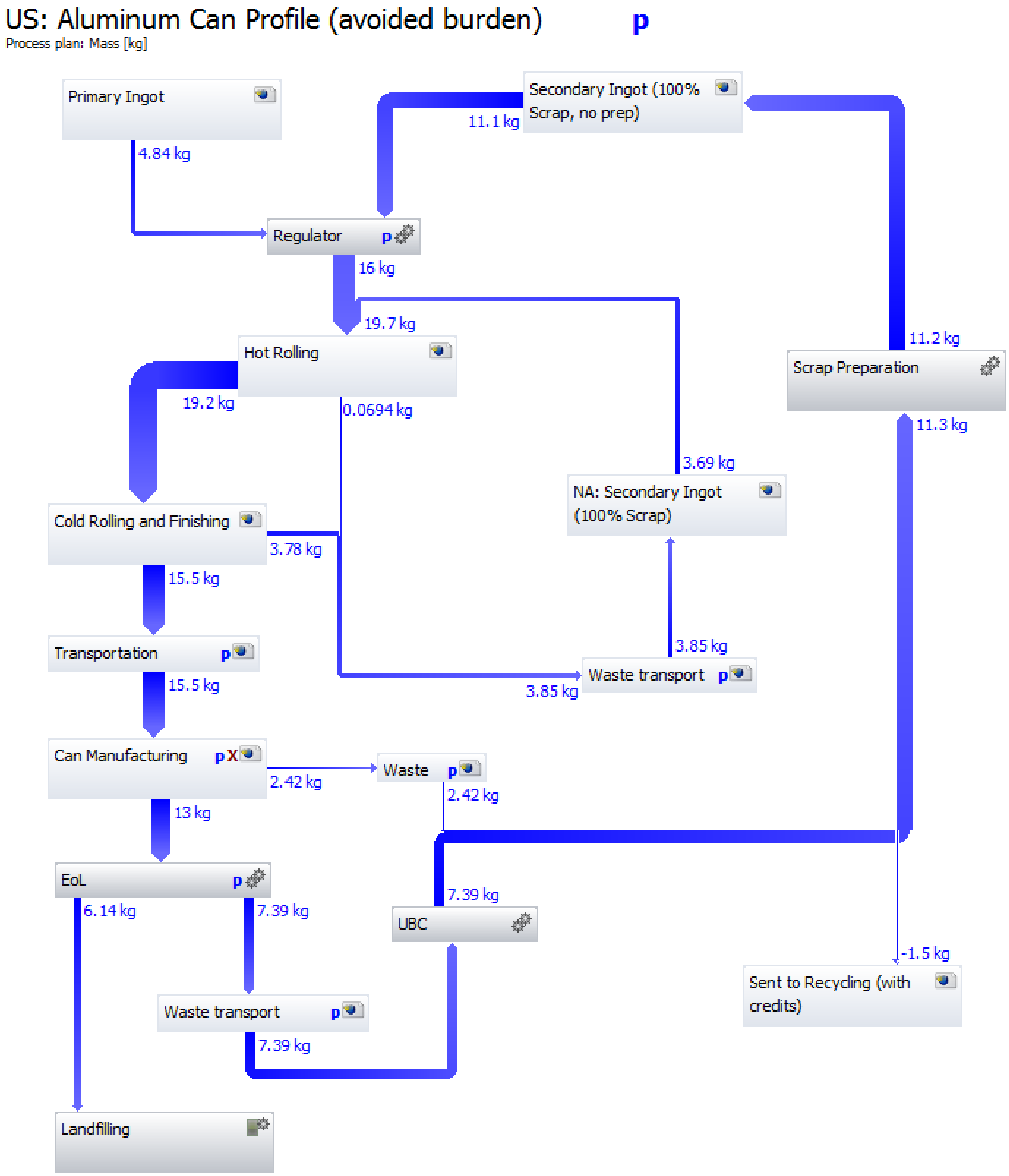

Figure 1. Avoided burden scenario

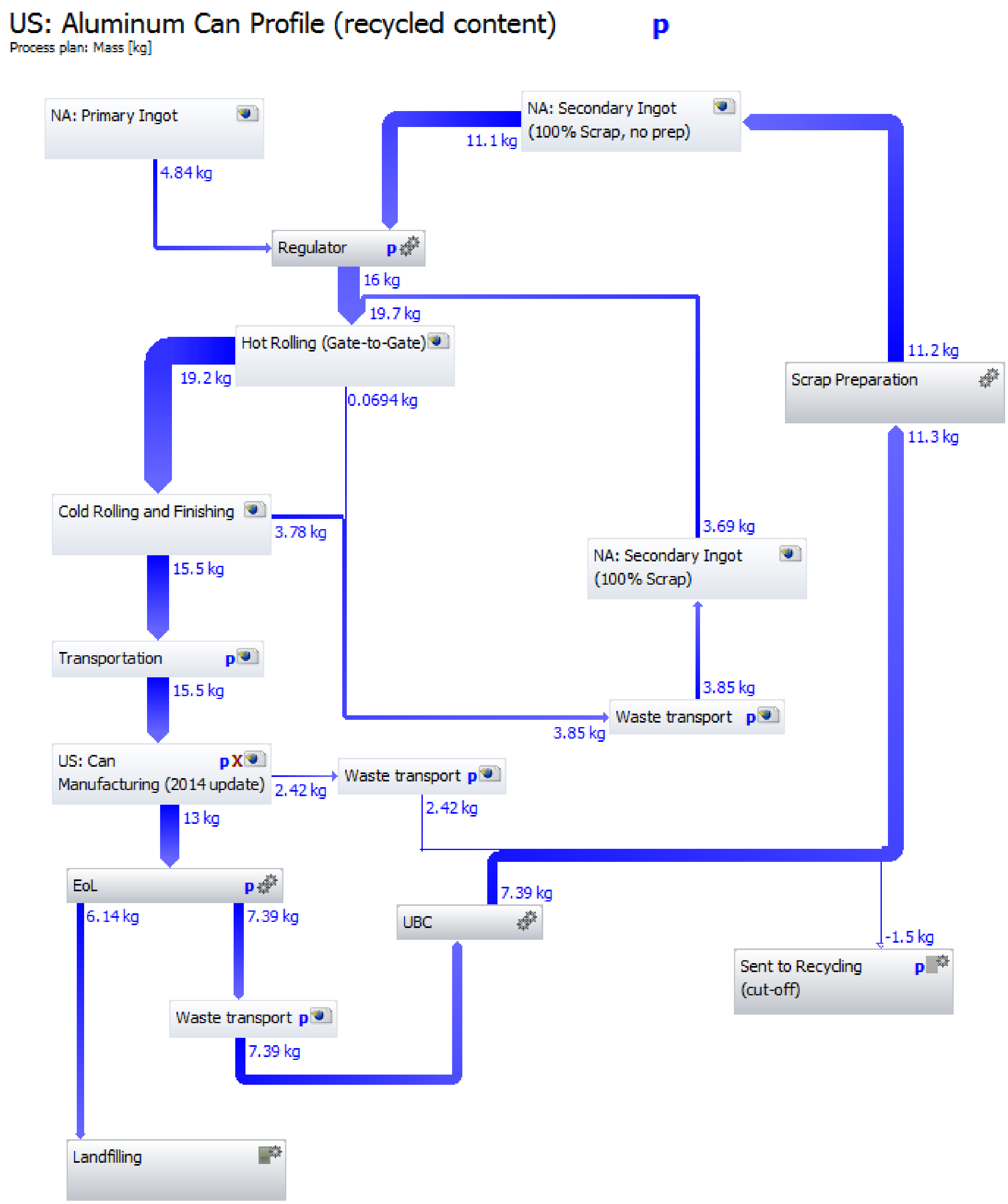

Figure 2. Recycled content scenario

RESULTS

Tables 3 and 4 present the LCI and LCIA results for the avoided burden and recycled content scenario, respectively. Across all indicators, the recycled content scenario has less impact than the avoided burden scenario; this is a direct consequence of the recycled content (70%) being higher than the end-of-life recycling rate (54.6%).

Figures 3 and 4 illustrate the breakdown of primary energy demand (PED) for the avoided burden and recycled content scenarios, respectively. The figures illustrate the source of the impacts in the life cycle (primary ingot, secondary ingot, rolling, can manufacturing, EOL recycling, other) and the type of energy (renewable vs. non-renewable). They demonstrate that the bulk of the energy consumption is related to the production of the primary ingot, followed by the can manufacturing and rolling processes. For the avoided burden scenario, the EOL recycling process (which accounts for the credit/debit of burden due to recycling UBCs) produces a net positive impact; more recycled content is used in the production of cans than is generated by the system at the end-of-life life, resulting in a deficit of scrap and, in turn, a burden associated with producing new material.

The general breakdowns and trends shown in Figures 3 and 4 would be similar for most other impact categories, including global warming potential.

Table 3. Selected results for the avoided burden scenario, per 1000 cans

Energy Consumption	**Value**	**Units**
Primary Energy Demand (PED)	1680	MJ
PED - Non-Renewable	1290	MJ
PED - Renewable	393	MJ
Aluminum		
Can Sheet Input	15.5	kg
2-Piece Can Output	13.0	kg
Air Emissions		
CO_2	95.6	kg
CO	0.0522	kg
NO_x	0.172	kg
SO_2	0.344	kg
VOCs	0.255	kg
Impact Categories (TRACI 2.1)		
Acidification Potential (AP)	0.490	kg SO_2-eq
Eutrophication Potential (EP)	0.0138	kg N-eq
Global Warming Potential (GWP)	104.6	kg CO_2-eq
Ozone Depletion Potential (ODP)	2.46E-08	kg CFC11-eq
Smog Potential (SP)	4.70	kg O_3-eq

Table 4. Selected results for the recycled content scenario, per 1000 cans

Energy Consumption		
Primary Energy Demand (PED)	1500	MJ
PED - Non-Renewable	1180	MJ
PED - Renewable	324	MJ
Aluminum		
Can Sheet Input	15.5	kg
2-Piece Can Output	13.0	kg
Air Emissions		
CO_2	85.5	kg
CO	0.0474	kg
NO_x	0.148	kg
SO_2	0.286	kg
VOCs	0.236	kg
Impact Categories (TRACI 2.1)		
Acidification Potential (AP)	0.414	kg SO_2-eq
Eutrophication Potential (EP)	0.0125	kg N-eq
Global Warming Potential (GWP)	93.0	kg CO_2-eq
Ozone Depletion Potential (ODP)	2.57E-08	kg CFC11-eq
Smog Potential (SP)	4.12	kg O_3-eq

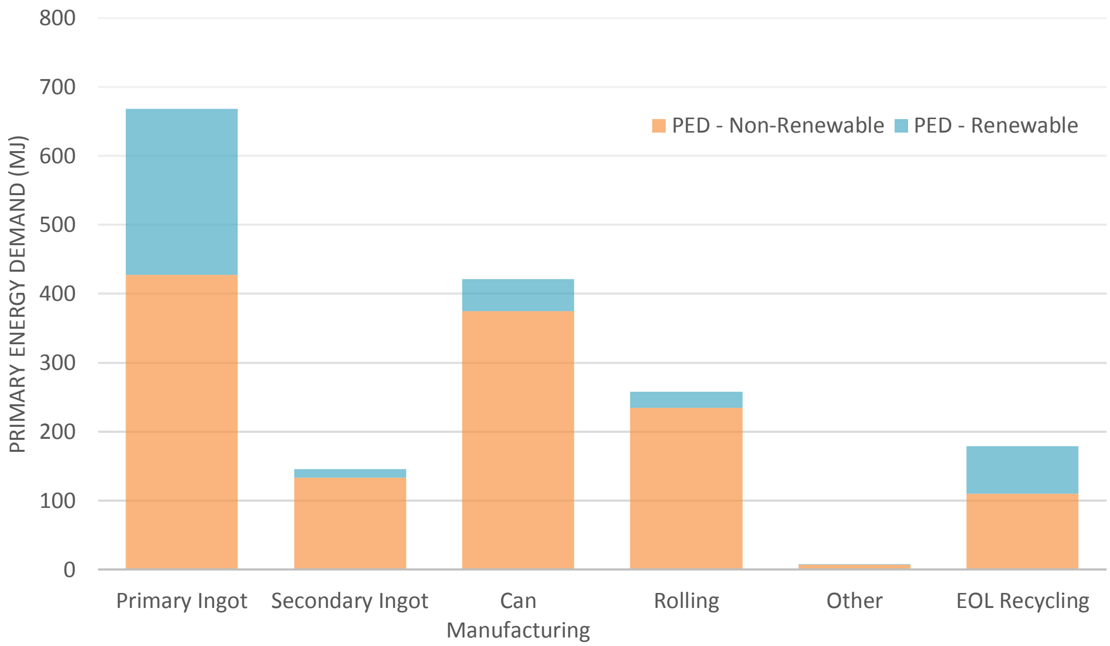

Figure 3. Breakdown of primary energy demand (avoided burden scenario)

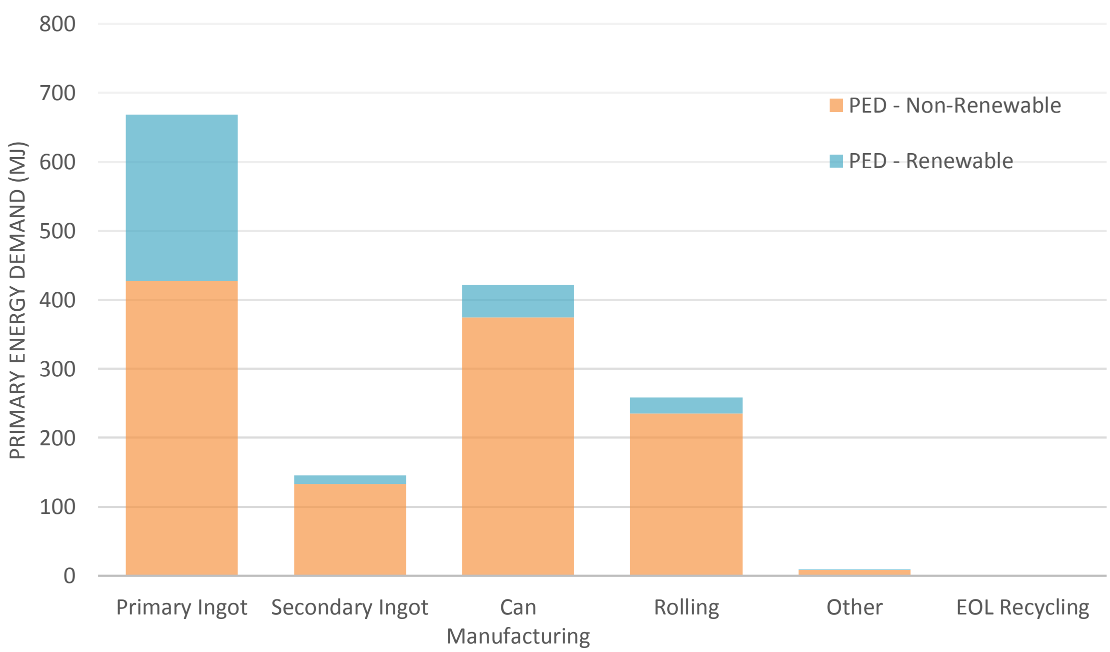

Figure 4. Breakdown of primary energy demand (recycled content scenario)

DISCUSSION

The results demonstrate that the primary ingot dominates the environmental footprint of aluminum cans. Even though the primary ingot makes up a relatively small portion (30%) of the aluminum used, its impacts outweigh those of the secondary ingot as well as those of the can manufacturing and rolling processes. Relatedly, issues surrounding recycling have a significant influence on the results.

Figures 5 and 6 illustrate the sensitivity of primary energy demand and global warming potential to changes in the end-of-life recycling rate and the recycled content, respectively. For the avoided burden scenario, the end-of-life recycling rate is 54.6%; any increase to this rate will cause the primary energy demand to decrease, along the line in Figure 5. For the recycled content approach, the recycled content is 70%; any increase to this rate will cause the primary energy demand to decrease, along the line in Figure 6. Note that changes to the recycled content will not affect the avoided burden scenario, nor will changes to the end-of-life recycling rate affect the recycled content scenario. Similar patterns will be observed for other environmental indicators.

Several relevant changes have been made the LCA since the 2010 study, including the following:

- New gate-to-gate data for can manufacturing
- Use of 2013 study data for aluminum ingot and rolling processes
- Recycled content changed to 70.0%
- End-of-life recycling rate changed to 54.6%
- Mass of can changed to 0.01304 kg.

The aggregate result of these changes are shown in Figures 8 and 9. For the avoided burden scenario, the primary energy demand has decreased approximately 14% between the 2010 and 2014 studies; the global warming potential has decreased approximately 20%. For the recycled content scenario, the primary energy demand has decreased approximately 11%; the global warming potential has decreased for approximately 18%. This reduction is likely due to a combination of factors, including the increase in recycled content and recycling rate[5], the reduced mass of the can, and/or changes to the aluminum ingot and fabrication processes. As the aluminum industry continues to improve efficiencies and increase recycling in its value chain, it is expected that further reductions can be realized.

Lastly, it should be noted that this memorandum does not constitute an ISO-conformant third-party peer-reviewed report. It only updates the data in the previous LCA study and has been quality assured within PE INTERNATIONAL.

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[5] The recycling rate in the 2010 study was an *industry recycling rate*, whereas the 2014 study uses a *consumer recycling rate*. The *industry recycling rate* is the annual rate of total numbers of UBCs melted by the aluminum industry in the United States (including can sheet producers, secondary aluminum producers, other casting or wrought aluminum mills who use aluminum scrap) plus the total numbers of UBCs exported, over the total number of cans manufactured and shipped. The rate includes UBCs imported from other countries. The *consumer recycling rate* provides a measure of the amount of domestic aluminum can scrap recycled as a percentage of cans shipped in the U.S. during a one-year time period. This rate excludes can scrap imported from other countries to provide a more accurate representation of consumer recycling behavior in the United States.

Figure 5. Sensitivity of PED and GWP towards the end-of-life recycling rate (avoided burden scenario)

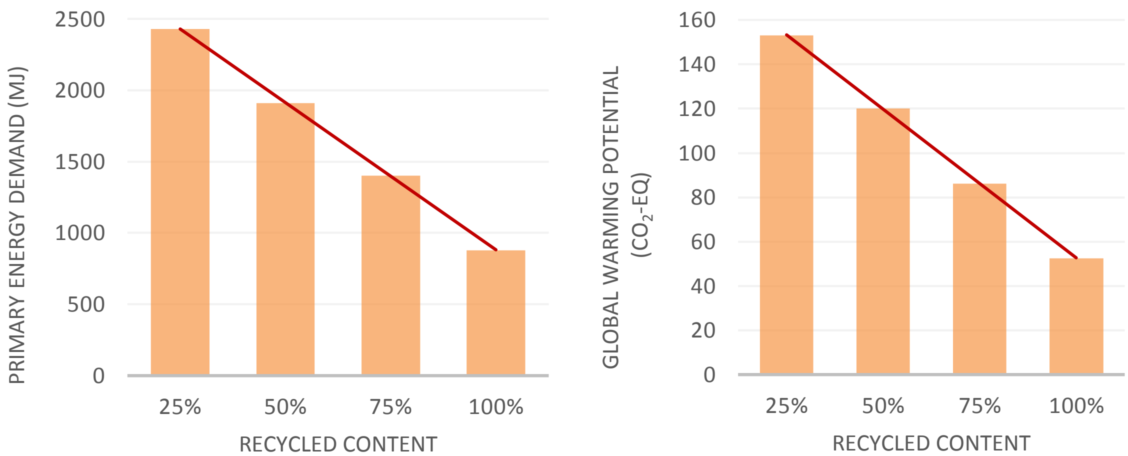

Figure 6. Sensitivity of PED and GWP towards the recycled content (recycled content scenario)

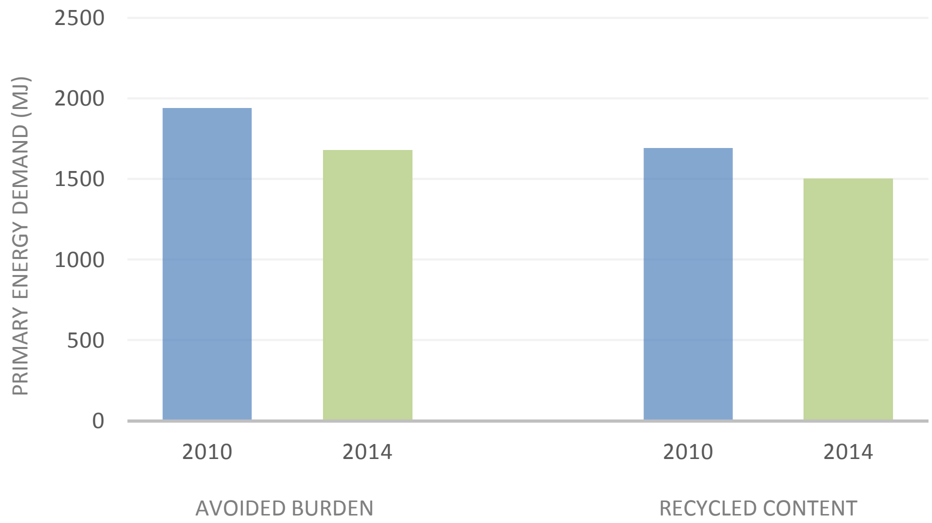

Figure 8. Comparison of primary energy demand: 2010 vs. 2014 study

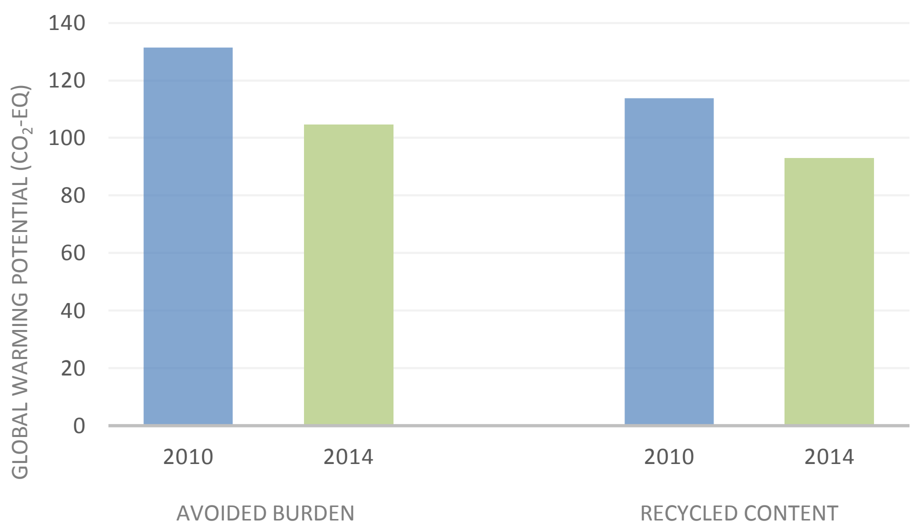

Figure 9. Comparison of global warming potential: 2010 vs. 2014 study

APPENDIX: SURVEY TEMPLATE

Figure 10. General data survey for can manufacturing LCI data

NAME OF FACILITY:		
CONTACT PERSON:		
EMAIL:		
(Please report quantities in metric tons or 1,000 pounds, please indicate your unit)		
	INPUTS	**OUTPUTS**
REMELT		
MOLTEN METAL (PRIMARY)		
MOLTEN METAL (RECYCLED)		
PURCHASED SCRAP (POST-CONSUMER)		
PURCHASED SCRAP (POST-INDUSTRIAL)		
PURCHASED SCRAP (MIXED INDUSTRIAL AND CONSUMER)		
PURCHASED RECYCLED METAL (RSI/SOW)		
PURCHASED PRIMARY METAL (INGOT/SOW)		
ALLOYING AGENTS		
OTHER PURCHASED METAL (Please Specify)		
RUN-AROUND SCRAP (NON-PURCHASED, FROM SAME FACILITY)		
CAST ROLLING INGOTS		
DROSS GENERATED		
NET METAL LOSS		
HOT & COLD ROLLING		
ROLLING INGOTS (from REMELT)		
ROLLING INGOTS (PURCHASED RECYCLED INGOTS)		
ROLLING INGOTS (PURCHASED PRIMARY INGOTS)		
FINISHED PRODUCT (CAN SHEET OR CAN END)		
RUN-AROUND SCRAP (RETURN TO REMELT AT SAME SITE)		
SOLD SCRAP (SOLD OR SHIPPED TO SISTER FACILITY OR TO THIRD PARTY)		

Figure 11. Detailed data survey for can manufacturing LCI data

					Raw Data from Facilities		
					Facility A (Name)	Facility B (Name)	Facility C (Name)
Inputs from Technosphere: Energy		**Energy via pipeline, truck, rail or barge (refers to all purchased fuels for combustion)**	**Units (GJ)**	Natural Gas			
				Crude Oil			
				Heavy Fuel Oil			
				Light Fuel Oil			
				Diesel			
				Propane/Butane			
				Kerosene			
				Coal			
				Coke Oven Gas			
				Refinery Gas			
				LPG			
				Purchased steam (from off-site)			
				Other (specify)			
		Purchased electricity	**Units (MWh)**	Electricity from grid (national or regional average grid)			
				Electricity from CHP (Co-Gen) Source			
Inputs from Technosphere: Materials		**Major materials**	**Units (metric tonne)**	Can sheet			
				Other, if any (specify)			
		Ancillary Materials	**Units (metric tonne)**	Acids, calculated as 100% H_2SO_4 (if other,please specify)			
				Hydrogen Fluoride			
				Nitrogen			
				Solvents (please specify name)			
				Lubricating oil			
				Ink (for painting)			
				Other coating material (other than ink, specify name)			
				Paper for packaging, if any			
				Wood for packaging, if any			
				Steel for packaging, if any (banding)			
				Plastic for packaging, if any			
				Cardboard for packaging, if any			
				Fresh w ater, purchased			
				Other (specify			

Figure 11 (continued). Detailed data survey for can manufacturing LCI data

				Raw Data from Facilities		
				Facility A (Name)	Facility B (Name)	Facility C (Name)
Outputs to Environment	Emissions to Air	Units (kilograms)	Particulate matter			
			SOx (as SO2)			
			NO2			
			N2O			
			Methane			
			Hydrogen chloride (HCl)			
			Hydrogen fluoride (HF)			
			Chlorine (Cl2)			
			VOCs, unspecified			
			Lead			
	Emissions to Water	Units (kilograms)	Organic substances (unpsecified)			
			BOD5, Biological Oxygen Demand			
			COD, Chemical Oxygen Demand			
			Chloride			
			Heavy metals, unspecified			
			Other (specify)			
	Emissions to Soil	Units (kilograms)	Filter dust			
Outputs to Technosphere (Product and Other Outputs)	Products & Co-Products of Beneficial Use	Units (metric tonne)	Beverage cans (2 PC)			
			Other co-products (specify)			
	Outputs to Off-site Recycling	Units (metric tonne)	Aluminum scrap			
			Waste oil, for fuel use			
			Waste ink or coating for recycling			
			Other (specify)			
	Outputs to Waste Treatment	Units (metric tonne)	Non-haz waste - sludge/grease/etc.			
			Filter dust waste			
			Hazardous Waste - coatings			
			Waste water release			
			General Trash and Wood			
			Other, if any (specify)			