Executive Summary

The life cycle assessment (LCA) study for the North American aluminum industry is carried out with the objective of generating up-to-date life cycle inventory (LCI) and life cycle impact assessment (LCIA) information for generic semi-finished aluminum products manufactured in the region. The information generated from the study includes all stages of the production chain from resource extraction to metal production and semi-finished product manufacturing, ending with product recycling and waste disposal. **Excluded in the study are final product fabrication and assembly, as well as the product use phase**. The time period of production activities included in this study was the production year of 2010.

The methodology used for the goal and scope definition and inventory analysis in this study is consistent with the methodology described in the ISO 14040/14044 Standards.

The intended use of the study is to:

- Establish an up-to-date life cycle inventory database for semi-fabricated aluminum products in North America. Such a database can assist the aluminum industry and its stakeholders in a variety of LCI data designated applications;
- Improve understanding of the potential environmental implications of product manufacturing and the overall life cycle burdens and benefits of aluminum products;
- Facilitate assessment of alternative production design options (for instance, alternative process design, technology, etc.), compare corresponding datasets, and guide the evaluation of modifications for improvement;
- Provide information for use in strategic planning and sustainable development;
- Develop communication messages such as Environmental Product Declarations (EPDs) and industry sustainability reports.

The study is not intended for:

- Use as the sole criteria in raw material or product selection decisions;
- Partially, selectively, or inappropriately being used to claim against the aluminum industry and its products;
- Use as a base for federal, state and/or local level government environmental regulations against the manufacturing activities of the aluminum industry.

Original production data of each individual unit production processes is directly collected by the Aluminum Association or the International Aluminium Institute (IAI), from more than 120 individual production facilities representing a large majority of the industry in North America. The collected data represents the following coverage in terms of reported tonnage to the total producer shipments of the industry in the region:

- Primary metal production: 95 percent
- Aluminum recycling/secondary metal production: 62 percent

- Extruded products: 59 percent
- Flat-rolled products: 85 percent (aluminum foil production is not included in the study)
- Shape-casted products: not applicable

The data is compiled to provide an aggregated LCI for each of the unit processes of the product systems. The data is then combined to develop roll-up “cradle-to-gate” LCI profiles for the examined product systems including:

- primary aluminum;
- aluminum recycling or secondary aluminum;
- extruded profiles;
- hot-rolled sheet and plate;
- cold-rolled sheet and plate; and
- cast shapes and parts.

The majority of the surveyed facilities provided data for the production year of 2010. However, a small number of facilities also provided data for the production year of either 2008, or 2009, or 2011 depending on their convenience of extracting records.

Life cycle impact assessment is conducted for each of the above mentioned product systems based on five selected impact categories:

- Primary Energy Demand;
- Global Warming Potential;
- Acidification Potential;
- Eutrophication Potential; and
- Smog Potential.

Cradle-to-grave LCIA is also examined by using the Avoided Burden methodology for the semi-fabricated product systems including extrusion, flat-rolling and shape casting. Again, the product fabrication phase and use phase are not included in the assessment.

A **complete transparency approach** is taken for this study throughout the processes including data collection, modeling and reporting. Information is disclosed at a maximum level where it is legally permitted. All significant input and output inventories are listed for each individual unit production processes. And a combination of results is provided for users with different purposes. Users without the same software tools for this study can use the basic information provided at each steps to construct their own models with their own tools to repeat the entire study.

The results of the study, in terms of “cradle-to-gate” and “cradle-to-grave” (excluding product fabrication/assembly phase and use phase) potential environmental impacts, are shown in **Table 1** and **Table 2**, respectively.

Note that the “cradle-to-gate” results for semi-fabricated products are based on the **actual mix of primary and secondary aluminium** being input into North American extruders, casters and rolling mills in year 2010. The “cradle-to-grave” results, on the other hand, are based on an assumed **end-of-life (EOL) recycling rate of 95 percent** for every product systems. It is a snapshot of potential full life-cycle impacts of the products when the use phase is excluded and when the indicated EOL recycling rate is achieved. This approach is consistent with the *Declaration by the Metals Industry on Recycling Principles* published in the International Journal on Life Cycle Assessments in 2007 (Atherton et al, 2007).

Table 1: Cradle-to-gate LCIA results of aluminum products, representing 1000 kg of products. Results for semi-fabrications are based on the actual mix of primary and recycled metals in these products.

Impact Assessment Category	Unit	Primary Ingot	Recycled Ingot	Extruded Products	Hot-Rolled Products	Cold-Rolled Products	Shape Cast Products
Primary Energy Demand	GJ/ton	138.10	11.09	102.44	61.81	84.86	43.65
Global Warming Potential	ton CO_2-eq/ton	8.94	0.67	6.57	3.94	5.34	2.75
Acidification Potential	kg SO_2-eq/ton	56.45	2.08	38	22	29	14
Eutrophication Potential	kg N-eq/ton	0.97	0.07	0.77	0.43	0.62	0.30
Smog Potential	kg O_3-eq /ton	445.69	25.04	327	187	250	118

Table 2: Cradle-to-grave LCIA results of semi-fabricated aluminum products, representing 1000 kg of products, assuming a 95 percent end-of-life recycling rate.

Impact Assessment Category	Unit	Extrusion Products	Hot-Rolled Products	Cold-Rolled Products	Shape Cast Products
Primary Energy Demand	GJ/ton	28.58	27.84	40.98	27.34
Global Warming Potential	ton CO_2-eq/ton	1.76	1.73	2.48	1.69
Acidification Potential	kg SO_2-eq/ton	6	7	10	7
Eutrophication Potential	kg N-eq/ton	0.25	0.19	0.31	0.19
Smog Potential	kg O_3-eq /ton	83	75	105	64

The study concluded with the following take-away messages:

- <u>**Energy Demand Key Driver of Environmental Footprint**</u>

The study shows that more than 60 percent the environmental footprints of the examined products are energy related. The generation of electricity, particularly from fossil fuel fired power plants, attributes to the largest share of the total footprint. The study also shows that of all the examined product systems, primary aluminum production accounts for more than 50 percent of the footprints (**Figure 1**). The semi-fabrication processes account for 11 percent, 13 percent, 22 percent, and 28 percent for extrusion, hot-rolling, cold-rolling and shape casting, respectively. Among the different unit processes of the primary aluminum production, electrolysis accounts for the largest share of footprint and most of it is due to fossil fuel fired electrical power generation at the energy supply chain.

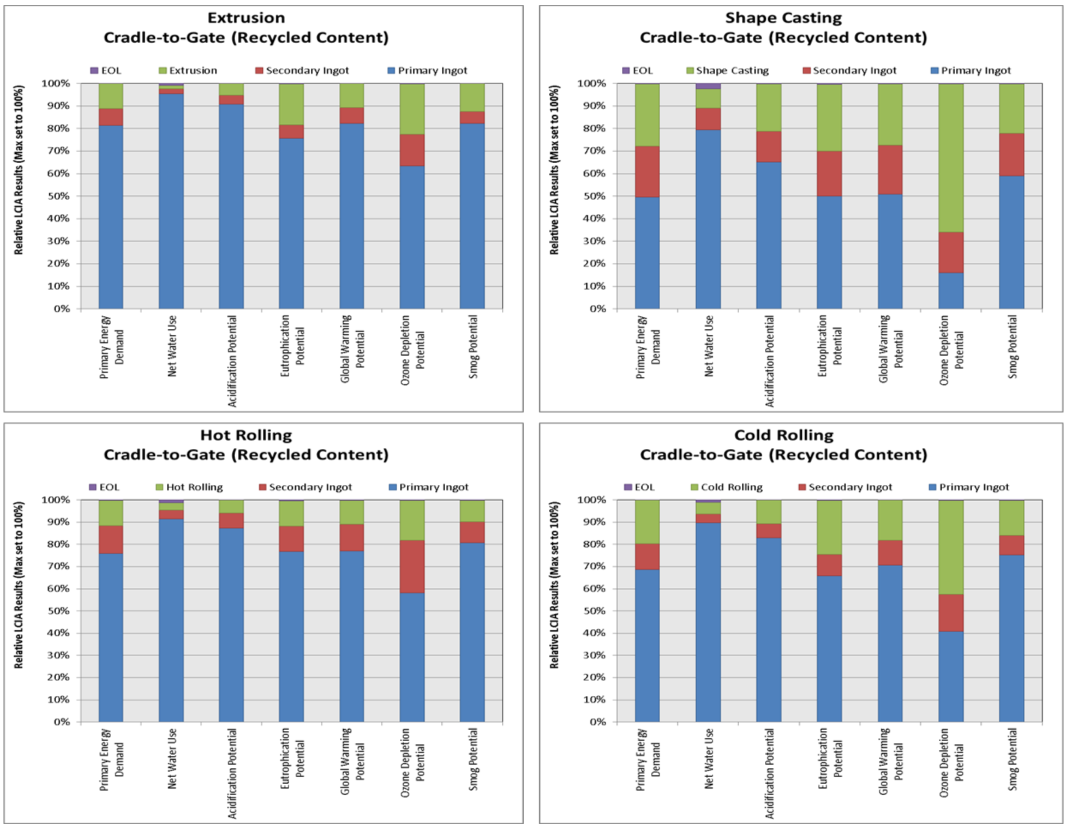

Figure 1: Breakdown of Cradle-to-Gate LCIA Results

- <u>**EOL Recycling Helps Significantly Reduce Footprints**</u>

Recycling of aluminum at the end of its useful life can significantly reduce the footprint and therefore the potential environmental impacts. The effect on primary energy demand and global warming potential by increasing EOL recycling rates can be seen from **Figure 2**. The figure shows that **each 10 percent increase in EOL recycling can reduce the overall energy demand and global warming potential by more than 15 percent** for all examined product systems. Similar effects can also be observed regarding to other impact indicators.

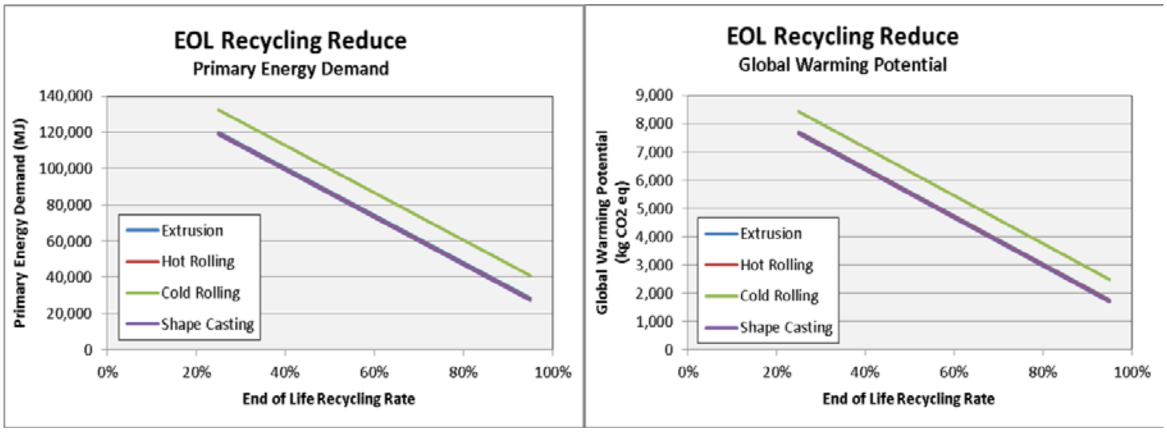

Figure 2: The impact of EOL recycling on the primary energy demand and global warming potential associated with semi-fabricated aluminum products

- <u>**Significant Footprint Reductions Achieved**</u>

Significant progress has been made in the aluminum industry in improving energy efficiency and reducing emissions. For instance, compared to the production year of **2005**, primary energy demand and global warming potential for primary aluminum production have been reduced **11percent** and **19 percent**, respectively. And compared to the production year of **1995**, the reductions were **26 percent** and **37 percent**, respectively (**Figure 3**).

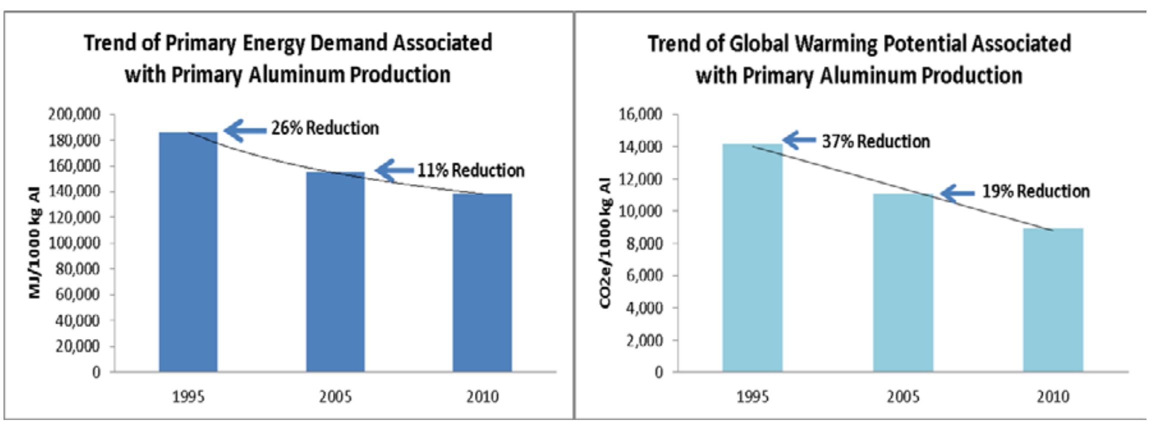

Figure 3: Trend of primary energy demand and global warming potential associated with primary aluminum production.

The progress is attributed to continuous improvement in energy efficiency and reduction in emissions through technological development, and the increasing use of renewable hydropower in the industry (**Figure 4**, **Figure 5** and **Figure 6**).

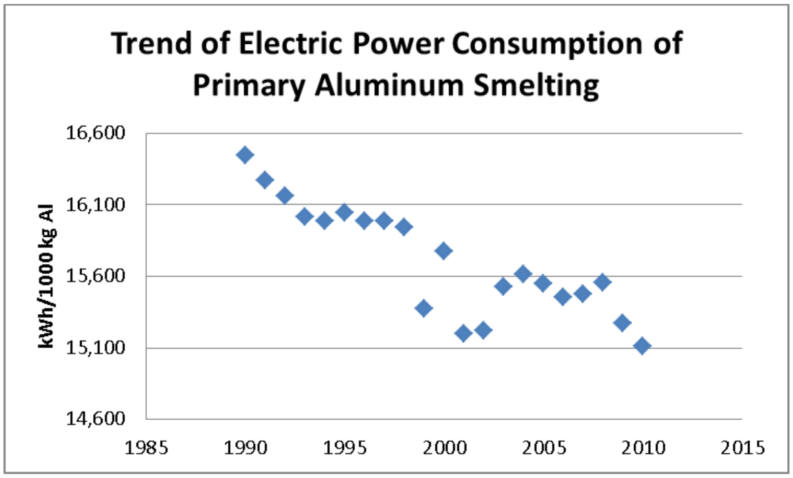

Figure 4: Trend of electric power consumption of primary aluminum smelting.

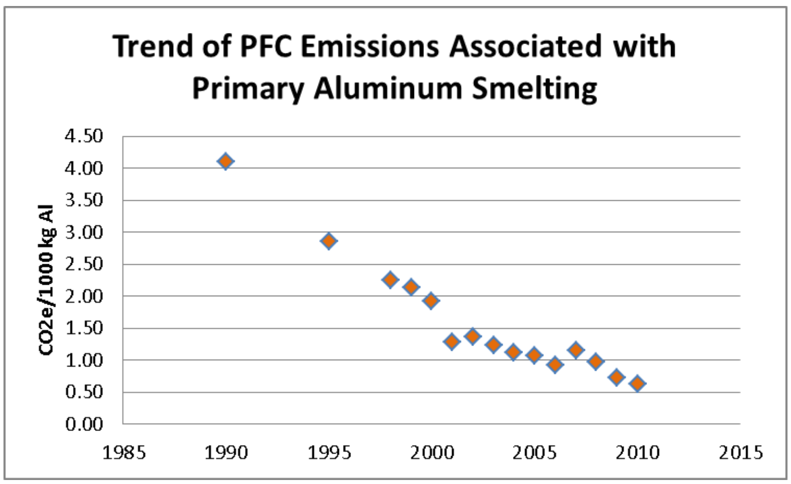

Figure 5: PFC emission intensity reductions (1990 – 2010)

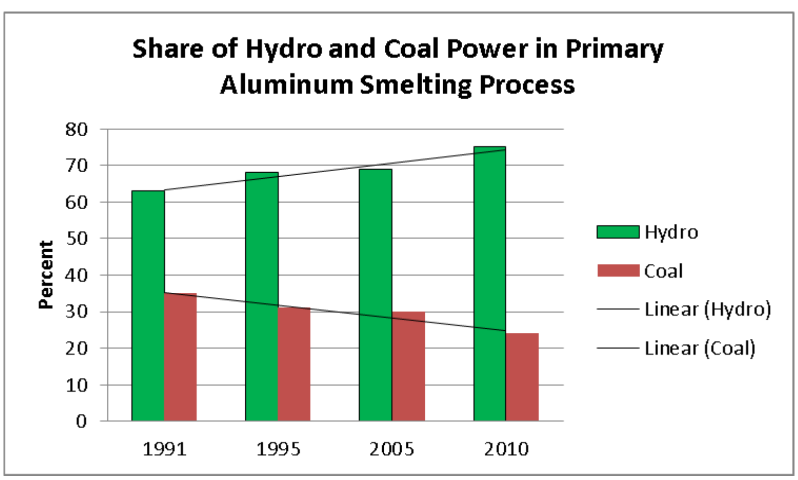

Figure 6: Relative shares of hydro power and coal fired power in primary aluminum smelting process (1990 – 2010).

- **<u>Product Use Phase Another Key Consideration</u>**

It is critical to note that the use phase of products, although not included in this study, could have the biggest impact on the overall life cycle environmental footprints. Users are therefore specially cautioned to draw conclusions before including the use phase in their studies. Many LCA studies show that the environmental footprint of the production phase of a product is minimal compared to the use phase impacts. This is true across almost all market sectors including building, packaging, transportation and consumer durables. For example, the production phase of an automobile is as less as 10 percent of the total life cycle footprint and the rest is due to the energy consumptions during the use phase. Aluminum as a strong and lightweight material in automobile can significantly reduce the energy consumption of the vehicle compared to a steel solution (both conventional auto steel and advanced high strength steel) and thus help reduce the overall life cycle footprint of the vehicle (Alain Dubreuil et al, 2010; Marlen Bertram et al, 2009; IAI, EAA and AA, 2008; Audi, 2005).

Compared to the production phase, the use phase is usually product specific and is not as straightforward. LCA practitioners shall pay special attention in their approaches to model the use phase so that it can be scientifically sound and practically accurate. This topic, although extremely important, is out of the scope of this study. The study itself is only the foundation for LCA users to build their use phase upon it.

- **<u>Increased Aluminum Use and Recycling Can Drive Future Improvements</u>**

Looking at the future, the aluminum industry is expected to continuously make progress in reducing product environmental footprints at the production stage. However, the extent of such improvement is often determined by the law of physics.

On the other hand, significant reduction of future life cycle footprints of aluminum products can be achieved through increased aluminum use and EOL recycling.

As stated previously, the use of aluminum could substantially improve the overall environmental footprint of a product. Aluminum light-weighting solution for passenger cars and light trucks with the assistance of improved powertrains will increase the fuel economy significantly by 2025 and therefore reduce the overall footprint of the North American passenger fleet. The Ducker Worldwide, an independent material research organization, has forecasted that the use of aluminum in cars and light trucks will be doubled upon the current level by 2025.

Aluminum is a perfect material for recycling and the recycling process does not change any functionality of the metal no matter how many times it is recycled. While aluminum products used for transportation, infrastructure, and building and construction have been historically mostly recycled at the end of life, the recycling rates for consumer products such as certain packaging and consumer electronic products are traditionally very low in North America. It is estimated that a significant amount of aluminum is lost in landfills each year in the region. The recycling of these lost metals will not only help the industry to reduce its environmental footprints, but also help the society to save the metals and its attached energy resources for future generations, thus achieving the ultimate goal of sustainable development for humanity.