Appendix B

1. Consequential life cycle assessment (CLCA) of old scrap recycling in Spain

Figure B.1 summarizes graphically both scenarios considered in this paper. The following stages were included within the boundaries of Spain: collection and sorting included in waste management, recycling, primary aluminium production, alumina production, bauxite mining and transport to all facilities. Data and explanations are given in the following section.

1.1. Life cycle inventories

1.1.1. Functional Unit

In this work, the functional unit has been defined as 1 ton of aluminium old scrap collected in Spain for recycling in Spain, China and Europe.

1.1.2. Inventory

Inventory data for bauxite mining, alumina production, liquid primary aluminium and ingot primary aluminium were based on information from Schmidt and Thrane (Schmidt and Thrane, 2009). We assumed the same mass balance in all scenarios: 4.6 kg of bauxite and 1.92 kg of alumina are needed for 1 kg of primary aluminium. However, we assumed an energy consumption in the smelting process of 15.3 kWh t^{-1} for global primary aluminium production but an energy consumption of 14.8 kWh t^{-1} for Spanish primary aluminium production (EAA, 2008; Alcoa, 2004). Data regarding old aluminum collection and transport to different facilities in Spain were estimated based on data from previous Spanish works (Rives, 2010; Retorna, 2011). Although these data were calculated for the Municipal Solid Waste (MSW) collection, we have assumed the same data for all the old scrap collection. All of the distances have been calculated using the EcoTransIT tool (Ecotransit, 2012). Data regarding the electricity and diesel consumption in sorting plants were provided by waste managers in Spain (not shown).

The inventory data for recycling was taken from ecoinvent (Classen et al., 2009) and EAA (EAA, 2008). In scenario A-global, we used transport distances provided by Schmidt and Thrane (Schmidt and Thrane, 2009), and we considered an average distance of 10,000 km from the primary aluminium production site to the semifinished plant production site. In scenario B-local, an average distance was assumed for the transport of bauxite to Spain (approximately 5,000 km).

1.1.2.1. Electricity inventory

The electricity mix is the critical factor regarding the environmental impacts of aluminum recycling, so we used the marginal electricity mix for aluminium smelters and the rest of the process (i.e., casting or remelting), depending on the scenario and the region or country profile. The marginal electricity mixes for the countries (i.e., China) and regions outside of Spain considered in scenario A-global and for the bauxite mining in scenario B-local were obtained from Schmidt and Thrane (Schmidt and Thrane, 2009), and Table B.1 and B.2 summarize the data used. We calculated the marginal electricity mix for the scenario B-local (Spain). In this case, we used data and projections from the Ministry of Industry, Energy and Tourism (Minetur, 2011), in which it was established that the structure of electricity generation in Spain will continue to evolve over the forecast period in the same way as it has done in recent years, with a reduction in the weight of oil and coal in the generation mix, a slight increase in the natural gas weight and greater growth of renewable energy and hydroelectric pumping (Minetur, 2011). Table B.3 summarizes the electricity generation in 2005, the forecast for 2015 and 2020 and the applied marginal electricity generation for Spain assumed in this study. As far as the authors know and based on information provided by the primary aluminium sector, there is no self-generation electricity in the primary industry; therefore, the marginal electricity mix was used for all the stages.

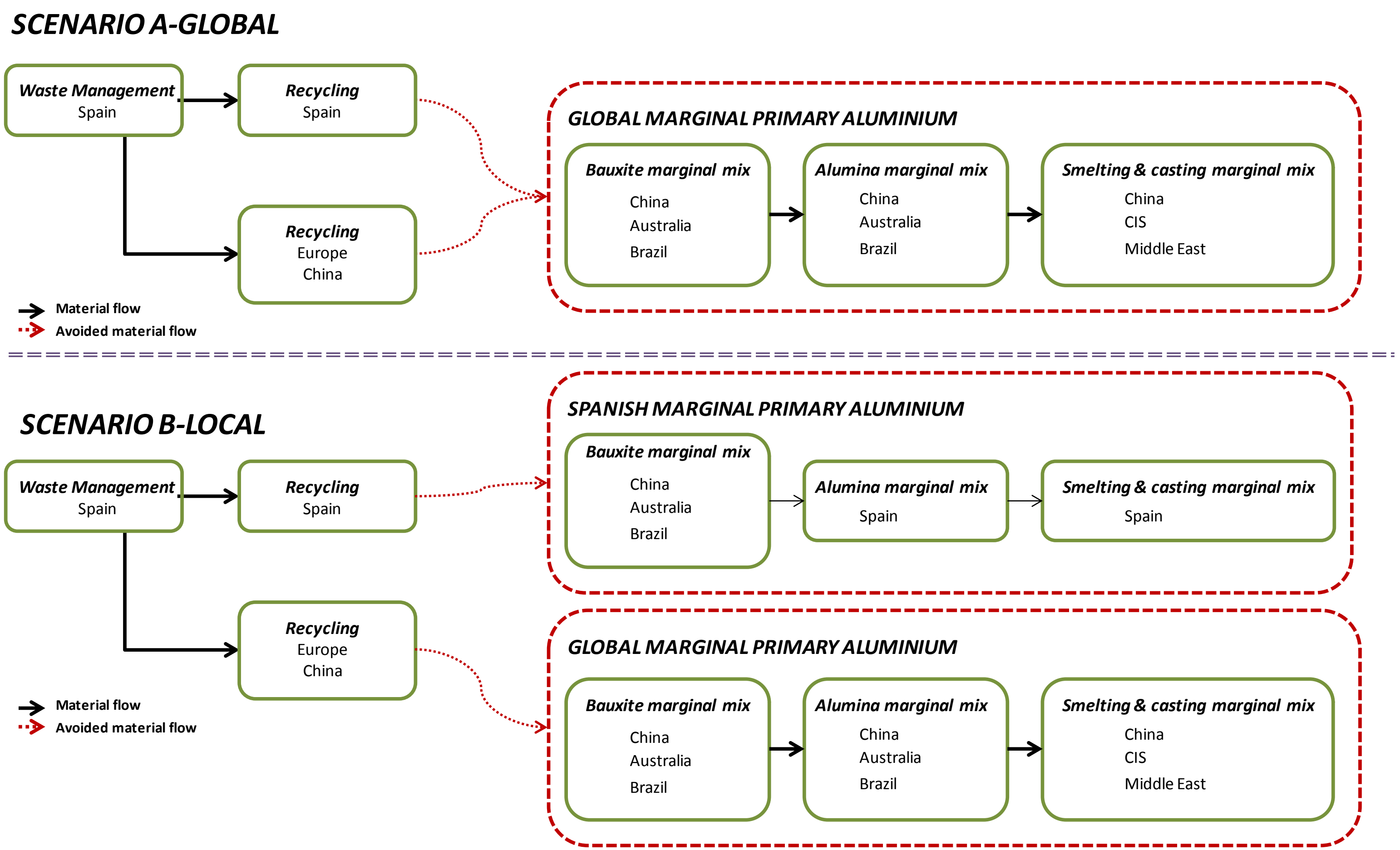

Figure B.1: Global marginal primary aluminium production avoided in scenario A-global and Spanish marginal primary aluminium production avoided in scenario B-local

Table B.1: Marginal electricity mix assumed for Europe and Asia for recycling (based on information from Schmidt and Thrane, 2009)

	Europe (%)	**Asia (China) (%)**
Coal	0.28	0.82
Gas	0.43	0.02
Nuclear	0.00	0.05
Hydro	0.29	0.11

Table B.2: Marginal mix electricity sources for bauxite mining, alumina production and the primary aluminium smelter and ingot stages.

Summary from (Schmidt and Thrane, 2009)

	Bauxite	**Alumina**	**Primary Aluminium (smelting and casting)**
	Marginal electricity mix	**Marginal electricity mix**	**Marginal electricity mix**
Scenario A-global	49% Coal 8% Natural Gas 30% Nuclear 13% Hydropower	51% Coal 11% Natural Gas 22% Nuclear 15% Hydropower	62% Coal 9% Natural Gas 29% Hydropower
Scenario B-local	49% Coal 8% Natural Gas 30% Nuclear 13% Hydropower	94% Natural Gas 6% Hydropower	94% Natural Gas 6% Hydropower

Table B.3: Marginal electricity mix for Spain

Source of electricity	Generation 2005 (GWh)	Generation 2015 (GWh)	Generation 2020 (GWh)	Growth 2005-2020 (%)	Flexible	Applied marginal (%)
Coal	81,458	33,230	31,579	-49,879	No	0
Oil	24,261	9,149	8,624	-15,637	No	0
Gas	82,819	120,647	133,296	50,477	Yes	94.6
Nuclear	57,539	55,600	55,600	-1,939	No	0
Hydro (pumping)	4,452	6,592	8,457	4,005	Yes	0.06
Renewable	42,441	112,797	146,080	108,639	No	0

2. References of Appendix B

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