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# Strategic energy management in the primary aluminium industry: Self-generation as a competitive factor

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## HIGHLIGHTS

- Energy open market and supply volatility analysis.
- Energy savings, through modernization and efficiency gains in its production process.
- Impact of recycling in the environment through, mainly, reuse o aluminium from cans.

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## ABSTRACT

The Brazilian aluminium industry, classified as energy-intensive, consume alone about 6% of all power generated by hydro-electric power plants, and therein lies much of the problem: needs lots of energy to produce primary aluminium. The aim of this study is to evaluate the strategy of energy self-generation as a viable alternative of sustainable growth and its importance for the competitive primary aluminium industry in Brazil and outlines key tactics to self-generation adopted for different economic scenarios and conditions in which it would be effective. Also environmental aspects are considered because their impacts in costs and the impact of recycling in the environment through, mainly, reuse o aluminium from cans. Given the instability of energy prices on the open market and supply volatility, self-generation appears as the best alternative for maintaining the sustainability of the primary aluminium industry in Brazil.



## 1. Introduction

The power supply problem of the Brazilian industrial sector and in particular the energy-intensive one was extremely acute by the energy crises of 2001 and 2006 (Bermann, 2009). Industries such as cement, iron and steel, ferroalloys, non ferrous metals (e.g. aluminium), chemicals, and pulp and paper are considered industrial energy-intensive activities.

In fact, few years ago, Brazil had faced the threat of power rationing, which was due to the lack of planning and investment in generation and transmission of electrical power, according to Silva (2001).

About 90% of the Brazilian power generation is from hydro-electric power plants. In 2001, reservoir levels were found low, because the rainfall intensity was less than 75% of the annual average, and thus impair the plants capacity of generating. For this reason, there was even a series of blackouts that led to power rationing and a reduction target set at 20% for general consumption.

According to Andrade et al. (2001), companies such as Alcan (now, Novelis Inc.), Alcoa, and Kaiser were among those who decreased their production by choosing to sell power used in their operation, due to higher profitability in this business.

Boustead and Hancock (1981) highlighted the importance of the relation along energy and raw materials requirements in primary aluminium industry through their observation about data collected directly from relevant industries from this sector in the UK.

Also the impact in environment is relevant to industries of primary aluminium sector. The financial consequences for all energy-intensive industries, mainly primary aluminium ones have been observed by a revision on EU ETS (Emission Trading Scheme) from Euro Chlor (2010). Its commitment with reducing $CO_2$ emissions had been expressed by this company. Financial measures to compensate energy-intensive sectors, such as aluminium, are going to be adopted by member states of EU ETS for the additional costs of carbon passed through in electricity prices. Also Lund (2007) had investigated these cost impacts from European

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emission trading system on energy-intensive manufacturing industries, including primary aluminium sector.

Berkel (2007) related sustainability and operational perspectives, including economical and environmental aspects, to eco-efficiency through connexion of five 'prevention practices' (process design; input substitution; plant improvement; good housekeeping; reuse and recycling) with five 'resource productivity themes' (resource efficiency; energy use and greenhouse gas emissions; water use and impacts; control of minor elements and toxics; by-product creation). Other works, such as Schönsleben et al. (2010), had explained opportunities for energy-intensive industries based on sustainability and economic aspects and, more than this, their relationship.

According to Axelsson et al. (2009), the energy-intensive industry can be the major contributor to $CO_2$ emissions reduction, since that appropriate investments are made. In contribution to that, Axelsson et al. (2009) had developed a tool to evaluate energy market scenarios to analyse investments in energy-intensive industry, in accordance with the Kyoto protocol and the European Union commitment to decrease its $CO_2$ emissions.

Energy-efficiency policies for energy-intensive industries have been developed along the time. Some of these policies have considered environmental aspects, such as UK Climate Change Agreements models (Barker et al., 2007), where effects of policies adopted are estimated by their introduction into the energy-demand equations based on dynamic econometric model of the UK economy with fifty industrial sectors. Also Greening et al. (2007) evaluated models of industrial energy consumption, where they provided an introduction and context for a compendium or survey of the methods used in this area.

Thollander and Ottosson (2010) had studied the potential for energy efficiency in Swedish industry through the adoption of energy management practices with aim to describe and to analyse these practices in two different energy-intensive industries: the pulp and paper industry and the foundry industry. This study showed that majority part of industries do not allocate energy costs by means of sub-metering, which probably contribute to reinforce the split incentive problem.

Mongia et al. (2001) showed the impact of policy reforms on total productivity growth in India's energy-intensive sectors: aluminium, cement, fertilizer, iron and steel, and pulp and paper. Neelis et al. (2007) studied energy efficiency trends in the Dutch manufacturing industry between 1995 and 2003 using indicators based on publicly available physical production and specific energy consumption data.

Paulus and Borggrefe (2010) had investigated the technical and economic potential of energy-intensive industries to provide demand-side management (DSM) in electricity and balancing markets through 2030. In the same way, Schwarz (2003) had studied application of models in investment and implementation of technology in metal industries, specifically in German primary aluminium industry.

The Brazilian aluminium industry, classified as energy-intensive, consumes alone about 6% of all power generated by hydro-electric power plants, and therein lies much of the problem: needs lots of energy to produce primary aluminium. According to the Brazilian Aluminium Association (Brazilian Aluminium Association, 2004), it takes about 15 MWh to produce one tonne of aluminium.

Table 1 describes the main inputs for primary aluminium production highlighting the excessive consumption of electrical power Brazilian Aluminium Association (2004).

Electrical power is the major input for primary aluminium production after bauxite that is the raw material for this production. The aluminium industry depends on external support from power supply market, being vulnerable to common threats of the supply lack. Among them are:

- Vulnerability of supply: energy crises of 1987 and 2001 primarily to become extremely acute problem of supply not only for the aluminium industry, but also for the whole energy-intensive sector. Rationing was imposed at the time due to lack of planning and investment in generation and transmission of energy (Silva, 2001).
- Instability of prices: electricity represents about 35% of the cost of the metal obtaintion, hence its great importance. Among the available options, the free market and the wholesale energy market, instability is due to several factors, but mainly the lack of

**Table 1**
Inputs for primary aluminium production.

| Inputs for primary aluminium production | Base year 2003 |
|---|---|
| Alumina | 1919 $kg/t_{Al}$ |
| Electrical power | 15.0 $MWh_{DC}/t_{Al}$ |
| Cryolite | 8.0 kg/t |
| Aluminium fluoride | 19.7 kg/t |
| Petroleum coke | 0.384 $kg/kg_{Al}$ |
| Pitch | 0.117 $kg/kg_{Al}$ |
| Fuel oil | 44.2 kg/t |

**Table 2**
The Brazilian aluminium production (Brazilian Aluminium Association, 2009-1).

| Composition | 2007 | 2008 |
|---|---|---|
| Direct Jobs (December 31st) | 63,640 | 64,358 |
| Billing (US$ billions) | 14.3 | 16.1 |
| Share in GNP (%) | 1.1 | 1.0 |
| Share in Industrial GNP (%) | 4.4 | 4.3 |
| Investments (US$ billions) | 1.9 | 2.6 |
| Taxes paid (US$ billions) | 2.1 | 2.7 |
| Primary Aluminium Production (1000 t) | 1655 | 1661 |
| Domestic Consumption of Processed Aluminium (1000 t) | 919 | 1024 |
| Consumption per Capita (kg/inhabitant/year) | 4.9 | 5.4 |
| Export (1000 t) (weight aluminium) | 1067 | 964 |
| Import (1000 t) (weight aluminium) | 209 | 209 |
| Trade balance of the aluminium industry (US$ millions FOB)—including bauxite and alumina | | |
| Exports | 4759 | 4798 |
| Imports | 934 | 1025 |
| Balance | 3825 | 3773 |
| Share of aluminium exports in Brazilian exports (%) | 3.0 | 2.4 |