Opening the Automatic Frequency Restoration Reserve Markets in Europe: An Opportunity for Electrolysers

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Abstract

As electricity market liberalization progresses in Europe, more and more coupled ancillary services markets open in different countries. While large industrial plants were in the past already participating e.g. in frequency containment reserves (FCR), the opening in France of the automatic frequency restoration reserve (aFRR) brings with it new opportunities in terms of explicit flexibility revenues as well as related positive environmental impact. Indeed, providing such services with demand modulation allows conventional production means to operate at better efficiency. In November 2023 the aFRR market opened partially in France with the possibility of placing energy bids. Since mid of June 2024, the market is fully open with the capacitive part being operational.

In this paper, Energy Pool highlights the potential of energy flexibilities, both implicit and explicit, the evolving ancillary services market in France and other countries where they operate large industrial assets. In particular, the aFRR market opening and associated price level is discussed. The certification process of industrial assets such as electrolysers is presented: indeed, they are technically suited to operate on these high profitability markets. The associated economic and environmental benefits are documented as well for different electrolysis processes as for e.g. electrical boilers.

Keywords: Electricity market, Frequency containment reserves (FCR), Automatic frequency restoration reserve (aFRR), Energy bids, Electric flexibility, Energy Pool.

1. Introduction

Aluminium demand is expected to grow significantly in the coming decades because of increasing societal wealth, population growth, but moreover because aluminium plays a key role as material for constructing the energy transition e.g. in the needed cables, solar photovoltaic modules or lightweight automotive solutions. Being part of the solution for climate change mitigation, low emission aluminium becomes a necessity since it will decrease emissions during its production phase, but also impact massively the carbon footprint of these climate hazard fighting technologies that consist for a large and subsequently growing part of aluminium. In addition, the massive amounts of aluminium that are required in transport, in the energy sector of generation, storage and distribution or in the building sector need to be available at affordable costs so as not to slow down the pace of deployment of these new infrastructures.

2. Competitivity and Decarbonization by Activating Flexibilities

The US flexibility resources task force within the Energy Systems Integration Group states in its 2022 report [1] that "*Aluminum production … has an energy intensity of 71 gigajoules (GJ) per ton*", i.e. about 20 MWh while other sources report as much as 100 GJ/t direct energy for the entire cradle-to-cradle energy consumption, even including recycling (6.5 GJ/t) [2]. As such, it

accounts for 4 % of the global electricity demand and 3 % of the global greenhouse gas emissions worldwide [2] with the present mix. As stated formerly, the need for aluminium is expected to grow. According to Fortune Business Insight [3]: "*the market is projected to grow from USD 249.83 billion in 2024 to USD 403.29 billion by 2032, exhibiting a CAGR of 6.2 % during the forecast period*".

Aluminium production is thus an energy intensive industry (EII). Energy-intensive industries are a vital part of countries economy and play a critical role in reducing their strategic dependencies. EIIs contribute directly and indirectly, through downstream activities, to a large share of the economy, employment and innovation. They comprise industries such as chemicals, basic metals, non-metallic minerals (ceramics, glass and cement), plastics, paper products, wood and wood products, and food. Part of the EIIs include hard-to-abate activities. These are activities such as cement, glass, steel, chemicals and plastics production, which use fossil resources (coal, gas and oil) as fuel or feedstock. In these segments, greenhouse gas (GHG) emissions are comparatively difficult to reduce using current technologies. But aluminium production is excluded of these segments and has therefore a unique chance to be able to drastically reduce its GHG emissions.

The following Table 1, basing on data compiled in [2], presents, for each step in the aluminium life cycle (excluding usage, the related share of direct energy consumption, the associated GHG emissions and the amount of MWh of electricity per tonne for a conventional process.
Aluminium production relies on the electrolytic reduction of alumina in molten cryolite, a process that demands vast amounts of electrical energy.

Table 1. Value chain with direct energy consumption, associated CO_2 emissions and electricity need in MWh.

Process step	Direct energy (GJ)	CO2 emission (t/t)	Electricity share in the process energy (%)	Electricity need per tonne (MWh/t)
Bauxite & Alumina	23.3	2.6	7	0.45
Anodes & Smelting	52.4	13.2	98	14.26
Casting & Fabrication	7.1	0.7	33	0.65
Recycling	6.5	0.5	12	0.22

Accordingly, the main process electricity is consumed during the electrolysis process in the smelter. Due to the world average electricity mix being mainly based on coal, this production step accounts for 77 % of the CO_2 emissions associated with the production and recycling of one tonne of aluminium.
Thus, the most efficient measure to decrease the aluminium carbon footprint is to replace carbon intensive electricity by low carbon one in smelters operation. If one compares on this only base a tonne of aluminium produced in 2023 in France (mix 2023 = 32 g CO_2eq/kWh according to RTE [4]) or in China (582 g CO_2eq/kWh according to Statista [5]), the CO_2 content of the electricity needed for the smelting process will account for each tonne of aluminium 0.46 tonne of CO_2 in France and 8.3 tonnes of CO_2 in China. Even if the focus of the industries has been put on energy efficiency in the past and thus reducing the cost and GHG emission, the present rapid calculation shows that moving towards low carbon electricity will be by far more efficient in the carbon footprint reduction.

2.1 Implicit and Explicit Electrical Flexibilities

Electrical flexibility [6] refers to the ability of energy systems, in particular stand-alone or interconnected electrical systems, to adjust energy consumption or generation in response to

With such advanced control strategies, both implicit and explicit flexibilities are involved for lowering the global energy bill including gas and electricity and generating additional revenue from ancillary services to the grid.

8. Conclusions

Aluminium production accounts for 4 % of the global electricity demand and 3 % of the global greenhouse gas emissions worldwide. In addition, the need for aluminium is expected to grow and has to grow to provide materials for the energy transition. Therefore, the pressure toward low carbon aluminium is high and should be increasing in the years to come. While energy efficiency improvements were obtained in the last years, energy efficiency alone will not be sufficient to decrease drastically the GHG footprint of aluminium. Aluminium production needs cheap low carbon electricity. And by chance, renewable energies are providing such electricity but on an intermittent basis. Therefore, flexibilization of the aluminium production processes will be necessary both to synchronize consumption with production but also to support grid stability. To maximize their use of green electricity, aluminium production plants must become a kind of virtual batteries, ramping up in times of low or negative spot prices or locally consuming self-generated solar of wind energy. And in the same way as a battery, an aluminium production plant can stack revenues by offering its flexibility to the grid for balancing services. Indeed, with growing penetration of renewables the grids are more constrained and in need of more balancing power. The unique technical characteristics of electrolysers allows them to participate in the automatic frequency restauration reserve markets that are expected to be highly profitable in the years to come in high renewable energy share geographies. Thus economic, environmental and social impacts are perfectly aligned for aluminium production in such grids.

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