DEMAND-SIDE RESPONSE & FLEXIBILITY: KEY CONSIDERATIONS FOR THE EUROPEAN ALUMINIUM INDUSTRY

POSITION PAPER

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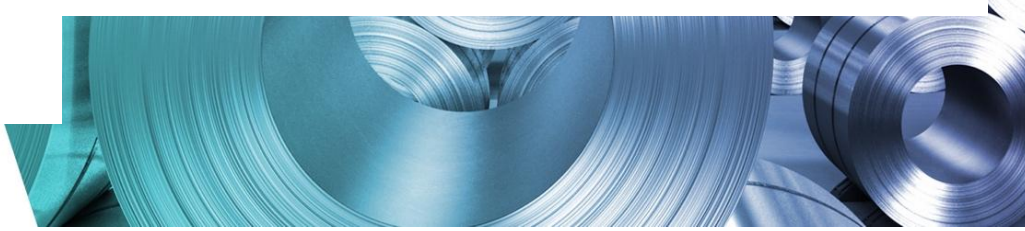

Background

The drive to decarbonise the electricity sector, electrify and decarbonise existing electrified industries is placing growing pressure on electricity grids that are not yet prepared to meet existing and increasing demand at cost-competitive levels.

It is also creating new challenges for preserving the balance between power supply and demand. While expanding renewable generation, storage and upgrading grid infrastructure are vital long-term solutions, Demand-Side Response (DSR) strategies can also contribute to accelerating the uptake of renewables in the system and reducing overall electricity generation during peak demand periods while supporting the decarbonisation of electricity grids.[1]

DSR is a type of grid balancing strategy that involves shifting consumption patterns to temporarily reduce or increase normal energy use to adjust to the immediate, hourly, daily, weekly or seasonal fluctuation of generation and consumption, improving the utilization of existing infrastructure (e.g., power lines) and reducing the risk of blackouts.

Electricity consumers are asked to adjust their consumption, providing flexibility to the electricity system, in response to external signals, price signals or to specific requests.[2]

According to ACER's report on flexibility, the electricity system in Europe will require more than twice (2.4 times) the current quantity of flexibility resources by 2030 to keep pace with evolving needs.[3] In the context of the Electricity Market Design, Member States already have to assess their flexibility needs at national level and may design adequate support schemes for flexibility, where needed.

On the supply side, flexible generation and storage solutions can respond rapidly to fluctuations in renewable output. Supply-side flexibility is expected to cover most of the flexibility needs, which primarily result from the transition to an electricity grid that depends increasingly on intermittent RES. Indeed, SmartEn estimates that industrial demand response will represent 3% of EU's peak demand in 2030.[4]

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[1] Sandbag, *Metallurgical flexibility: Enabling the aluminium and steel sectors for demand response*, 21 October 2024 [link].
[2] Stede, J., Arnold, K., Dufter, C., Holtz, G., von Roon, S., & Richstein, J. C., *The role of aggregators in facilitating industrial demand response*, 2020 [link].
[3] ACER, *Flexibility solutions to support a decarbonised and secure EU electricity system*, September 2023 [link].
[4] smartEn, *Demand-side flexibility: quantification of the benefits in the EU*, 6 October 2022 [link].

On the demand side – where possible technically and economically -, responsive loads can shift consumption to periods of lower demand or higher renewable availability.

However, energy-intensive industries core business is to produce, with due consideration of commercial contracts. With that in mind, demand-side flexibility from industry, particularly baseload ones, faces economic barriers, technical including safety concerns, and organizational constraints.[5]

In this paper, we provide a detailed overview of the challenges the European Aluminium value chain faces today.

Technical specificities of the aluminium industry

Primary aluminium production is one of the most electricity-intensive industrial processes, with electrolysis consuming between 13 and 16 MWh per tonne of aluminium, making electricity the largest operating cost. Smelters traditionally require a stable power supply to maintain the thermal balance of the electrolysis process, during which alumina is dissolved in molten cryolite at around 950˚C. Their voluminous, stable and predictable load supports the integration of variable renewables by maintaining demand during off-peak hours—reducing curtailment, stabilising prices, and limiting volatility in the power system.

Limited flexibility can be achieved by briefly and almost instantaneously reducing power consumption through potline voltage adjustments or short-duration potline shutdowns. This heightens the utilization of existing power lines and helps prevent blackouts, as demonstrated in EU Member States such as Germany and Greece.[6] Yet, **participation in DSR – same as all other minor disruptions – is constrained by the long recovery times needed to restore stable production and peak efficiency, *strongly* increasing energy consumption, carbon intensity, and operational costs.** Indeed, the electrolysis process requires a cooldown period to re-find its equilibrium and reduce the risk of impurities in the produced metal. For instance, an upcoming study shows that even interruptions under one hour can cost around €900/MWh, including ~€300/MWh in lost production, ~€100/MWh in anode costs, and ~€150/MWh from efficiency losses, raw material use, and equipment degradation.[7] In sum, aluminium smelters face technical limits to the number and duration of disruptions, making it difficult to adjust consumption to variable renewable energy and fluctuating power prices.

Conversely, the alumina refining process – the upstream precursor for the production of primary aluminium via electrolysis - can support DSR by switching from natural gas to electricity during periods of abundant renewable energy supply and reducing electricity use to zero during times of low renewable output. Currently, most of the heat required for the digestion in alumina refining (240–280°C) in Europe is generated by combusting fossil fuels - primarily natural gas. Integrating electric heating technologies alongside existing boilers could enable flexible fuel switching, reducing carbon emissions and helping grid operators minimize

[5] See Policy Recommendations from the Antwerp Dialogue on Industrial Electrification & competitiveness, December 2024.
[6] European Commission, *State aid case SA.38711 – Interruptibility Scheme in Greece* [link]; BBH Blog, *Demand Side Management*, 14 December 2015 [link].
[7] Compass Lexecon for Metlen, *Industrial Power Consumption in Europe: Opportunities for the Power System*, to be released.

curtailment of renewable generation. Thus, DSR policies should also consider flexible fuel switching rather than focusing solely on load shifting.[8]

For DSR to be viable for the aluminium industry, compensation from the electricity market and/or dedicated support instruments for DSR must exceed the lost revenue from the reduced output of the commodity and the additional costs incurred during the recovery period caused by the disruption. Given the complexity of operations and the variability in costs between plants, a one-size-fits-all compensation scheme is unfeasible. Instead, tailored agreements would be necessary to ensure fair and adequate compensation, allowing smelters or other industrial processes to contribute to grid stability without jeopardising their operational and financial viability.[9]

To ensure that DSR policies support grid stability without undermining the competitiveness of the European aluminium industry, the following key principles must be followed:

1. **DSR must recognise sector-specific constraints:** Load shifting is not a one-size-fits-all solution. Technical and economic factors vary across industries, and DSR policies must account for the technological limitations of sectors like aluminium by avoiding sector-agnostic benchmarks or flexibility targets that do not reflect industrial realities. Comprehensive data assessments are vital to map and maximise flexibility potential across industrial sectors and regions and ensure that industries that cannot incorporate flexibility in their industrial process are not disadvantaged.

2. **Location matters – DSR policies must avoid regional discrimination:** Energy markets, bidding zones, energy mixes, and network tariffs differ across EU Member States. For instance, the estimated all-in DSR costs range from below 100 euros in Member States like the Czech Republic to between €500 and €600 in Member States like Ireland.[10] Any upcoming reforms to network charges like the recommendations and guidance on harmonized tariff methodologies for network charges announced in the Clean Industrial Deal should lower or at minimum maintain network charges for industrial consumers. A blanket approach to load shifting could unfairly disadvantage aluminium producers in certain regions.

3. **DSR must be voluntary, fairly compensated, and never punitive:** Mandatory DSR would amount to forced curtailment, capping production and disadvantaging less flexible market participants. To ensure DSR remains voluntary and effective, it must be incentivised through high remuneration (e.g., expedited grid connection, reduced transmission tariffs, grid charges or market-based valuation) rather than imposed as an obligation.

   To incentivize more DSR from the aluminium sector, the regulatory barriers preventing the resale of PPA electricity should be removed to allow consumers to resell electricity when they are not consuming and

[8] European Commission, *Innovation Fund Project Summary: AAL SEB – Using Flexible Electrical Demand to Facilitate Higher Levels of Renewable Energy*, July 2022 [link].
[9] Sandbag, *Metallurgical flexibility: Enabling the aluminium and steel sectors for demand response*, 21 October 2024 [link]; Council of the European Union, Note 6567/24, *Flexibility, an essential tool to achieve the energy transition – Exchange of views*, 26 February 2024 [link].
[10] DG Energy (2016). *Impact Assessment Study on Downstream Flexibility, Price Flexibility, Demand Response & Smart Metering: Final Report*, July 2016 [link].

improve market liquidity. Additionally, interruptibility schemes must offer fair compensation, and network tariffs should remain affordable, with costs fairly distributed among producers' and consumers' ability to pay.

4. **Aluminium production is a commodity business focused on metal output, not energy trading:** DSR should avoid reductions in aluminium and alumina production, given their strategic role for supporting the EU's green, defense, and digital transitions. Therefore, DSR can and will only serve as a secondary revenue stream. Unlike power producers, aluminium companies are not structured to engage in complex and granular power exchanges. While grid flexibility is important, DSR alone will not solve Europe's energy challenges—more low-carbon electricity generation and storage at competitive prices is essential.

Example in the Aluminium sector - TRIMET Virtual Battery (Essen, Germany)[11]
Innovative technologies, such as TRIMET's Shell Heat Exchanger (SHE) system, are enhancing the aluminium industry's potential for DSR. At TRIMET's Essen plant in Germany, heat exchangers and a new control system have been implemented on 120 pots, allowing greater control over heat loss and enabling stable operations within a broader amperage range. This technology effectively turns the smelter into a 'Virtual Battery' for the grid by allowing power consumption to be adjusted without compromising production stability.

Example in the Aluminium sector – Hydro's Virtual Transmission Line (Sunndal, Norway)
Aluminium smelters can maximize grid capacity by rapidly shutting down consumption, giving transmission system operators (TSOs) time to restore balance after outages. For example, Hydro has partnered with the TSO in Sunndal to reduce smelter power use during transmission line outages in exchange for remuneration. This effectively increases regional transmission capacity by the smelter's consumption, creating a "virtual transmission line."

Example in the Alumina sector - Aughinish Alumina Ltd (AAL) Renewable Energy Boiler (REB) (Limerick, Ireland)[12]
The REB project is a first of a kind application of a high-temperature, high-voltage and high-pressure electric boiler substituting a gas-fired boiler within an energy intensive industry. The REB has been in operation for one year and operates when there is an excess of renewable energy on the grid. To provide a constant supply of steam to the refinery, the plant's gas boilers output turns down when the REB is running and vice versa. When not producing steam, the REB remains on 'Hot Keeping' and can achieve full output within ten minutes. Whilst to date the operating limit of high-pressure electric boilers has been 30Barg, the REB operates at 52.5barg and has a design pressure of 62Barg. This allows the REB to replace nearly 10% of steam demand, avoid up to 5% of site GHG emissions and reduce renewable curtailment.

[11] N. Depree, R. Düssel, P. Patel & T. Reek, *The 'Virtual Battery' — Operating an Aluminium Smelter with Flexible Energy Input*, 2016 [link]; See also Trimet's website here , EnPot website here and a Light Metals article of 2016 here.
[12] European Commission, *Innovation Fund Project Summary: AAL SEB – Using Flexible Electrical Demand to Facilitate Higher Levels of Renewable Energy*, July 2022 [link].

For more information on European Aluminium's work on climate and energy related policies, all papers, external studies and memos are available at the "Climate & Energy Section" of our Website.

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