Industrial power consumption in Europe: opportunities for the power system

Executive Summary

Fabien Roques and Florian Bourcier

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The study provides an analysis of the value associated with industrial power demand in a decarbonising EU power system

Context:

The EU power system is undergoing major transformations. By 2050, ENTSOE projects a penetration of variable renewables in the generation mix that reaches c. 80% (Distributed Energy scenario, 2050), and an almost complete phase-out of conventional fossil-fuelled power plants currently in use.

Industrial power consumption could represent 40 to 70% of the EU's electricity consumption by 2050, and thus is considered a material opportunity for the system to be operated reliably.

This Executive Summary provides the key take aways from the full study.

Study's content and main takeaways:

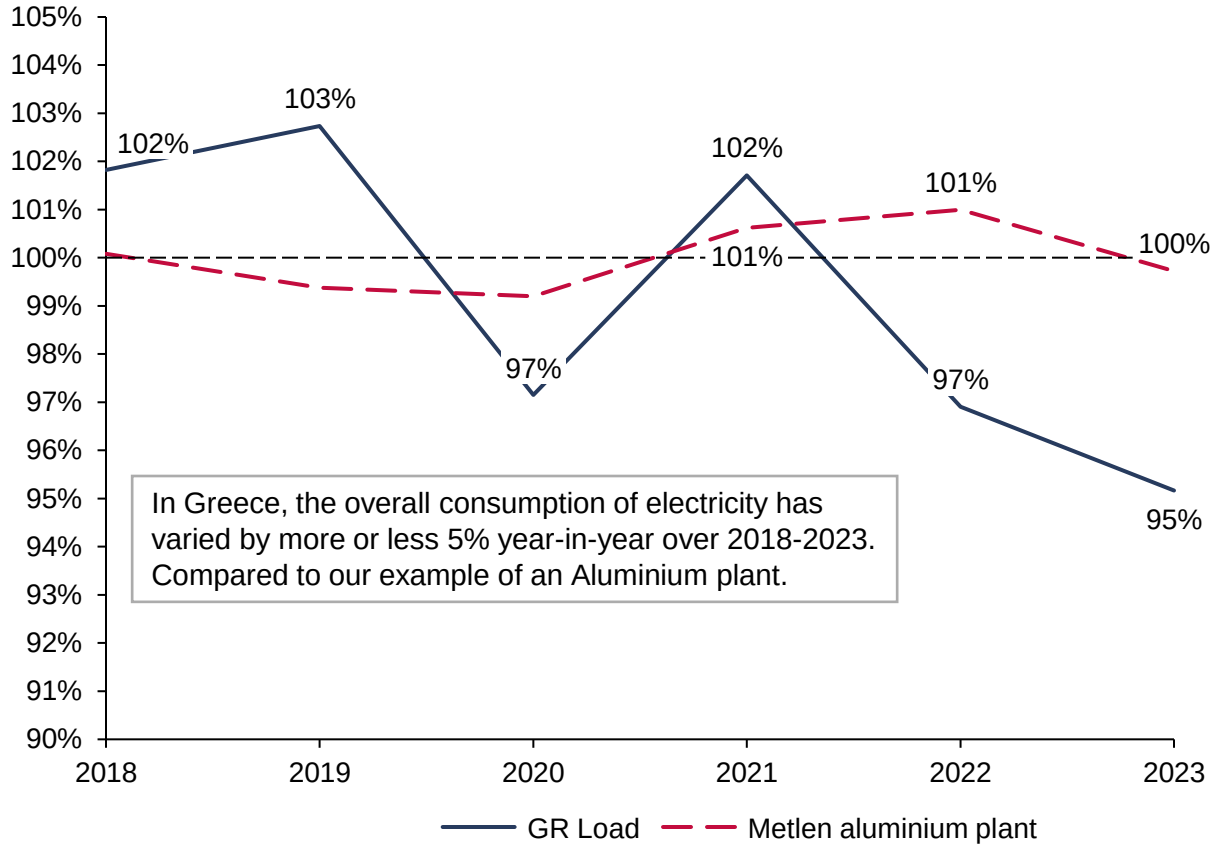
1	The **long-term predictability** and **geographic concentration** of industrial demand is an opportunity for optimizing the power system
2	The **shape of industrial load** contributes to efficient system operation by **offtaking low-carbon production** when demand from other sectors is low
3	**Industrial load flexibility** has substantial potential to support efficient power system operations but requires a supportive regulatory framework

1 The long-term predictability and geographic concentration of industrial demand is an opportunity for optimizing the power system

Year-on-year variations in consumption of a given industrial site are limited for efficient plants, supporting optimal dimensioning and use of power networks

- Industrial consumption is typically less affected by weather parameters than the average demand;
- Thus, the long-term predictability of industrial load levels and shape alleviates some risks of over/under dimensioning network expansion projects ; and
- It contributes to minimizing the development and operational costs of the power system.

Annual consumption of Metlen's aluminium plant and overall load in Greece – 2015-2023 [base 100 average load][1]



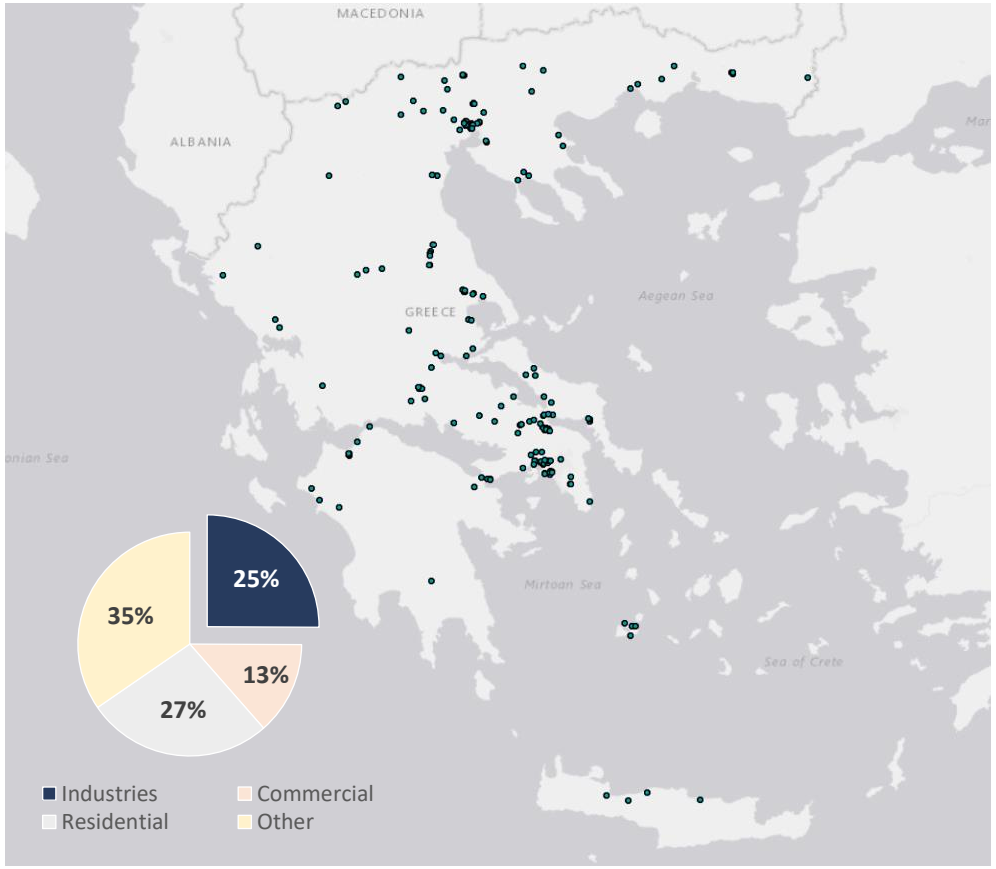
Source: *CL Analysis, ENTOSE Transparency (Greek load)*
Note: *[1] Macro-economic crisis may decrease industrial load in periods of very high commodity prices and/or decreasing demand.*

1 The concentration of industrial electricity consumption could be an opportunity to coordinate an energy transition roadmap

Industrial energy consumption is concentrated in a few sites allowing for coordination and planning of their energy needs.

- In Greece, a few hundred industrial sites accounted for 25% of final energy consumption in 2022.
- This facilitates a coordinated energy system planning approach with industrials to deliver an integrated electrification roadmap.

Main industrial sites and final energy consumption shares by sector in Greece in 2022[2,3]



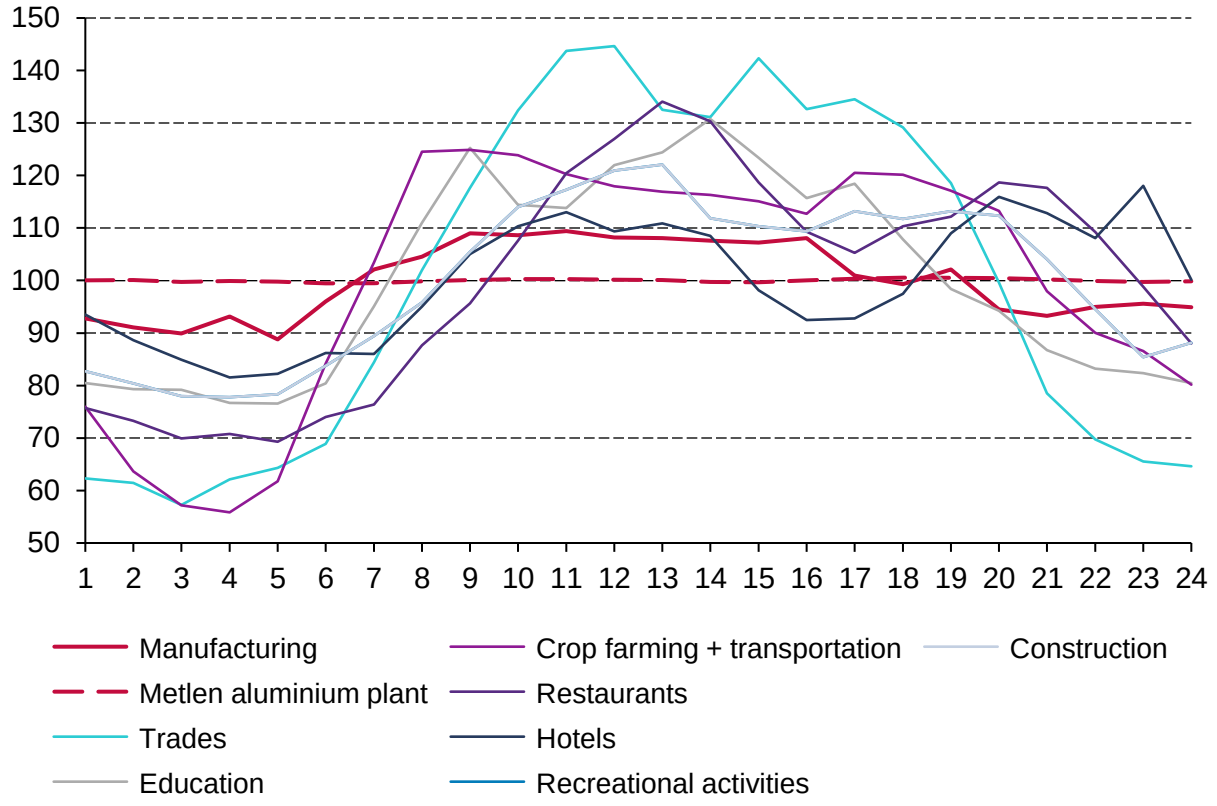
Note: *[2] https://industry.eea.europa.eu/explore/explore-data-map/map [3] Eurostat*

2 The shape of industrial load can contribute to efficient system operation by offtaking power when demand from other sectors is low

Industrial consumption is typically flatter than in other sectors during the day (e.g. residential or commercial) and supports demand when other sectors' demand is low, maximising the use of network infrastructure and supporting prices during off-peak periods.

- Hourly variations around the daily average consumption of an aluminium plant are negligible while the national consumption in Greece can vary four-fold in the course of a day.
- This supports efficient dimensioning and use of networks, which typically need to meet peak rather than average demand.

Characteristic industry loads in Greece and Metlen's aluminium plant over an average day (Hourly % of average load) [1]



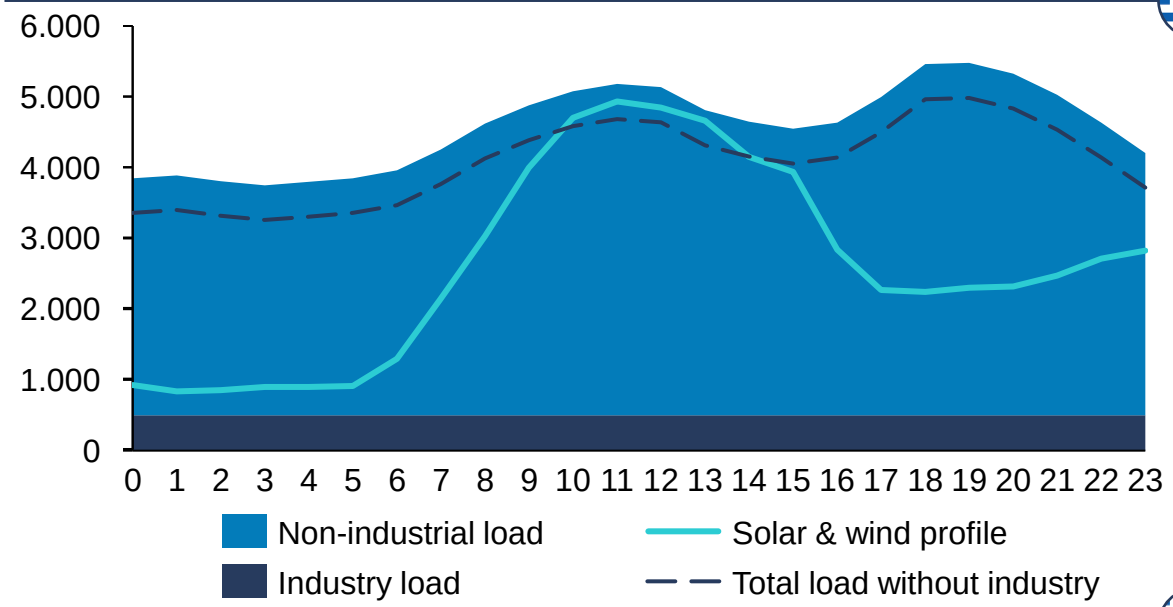
Sources: *[1] Bellinguer et al (2023), ELMAS: a one-year dataset of hourly electrical load profiles from 424 French industrial and tertiary sectors*
Notes: *The Metlen aluminium plant whose average load profile is indicated on the chart is located in Greece, and not in France*

2 The shape of industrial load can contribute to efficient system operation by offtaking low-carbon production

Industrial consumption is typically flatter than in other sectors supporting RES-E offtake and prices during off-peak periods.

- The loss of 500 MW of industrial baseload during periods with high RES-E generation could have caused about 130 GWh additional curtailment in Greece in 2023
- Similarly, industrial load supports power prices during off-peak periods by limiting the number of hours with excess renewable generation and the occurrence of negative prices.

Load and solar profile in a day in 2025 in Greece with and without 500 MW of industrial baseload (Based on demand from Sunday 12/03/23, MWh)



Focus on Greece case study:

- The Greek solar industry claims that 220 GWh were curtailed in 2023 and that this volume is expected to reach about 1000 GWh in 2024.
- Based on 2023 residual load, the loss of 500 MW[1] of industrial baseload during periods with high-RES generation could have caused about 130 GWh additional curtailment, reaching 350 GWh in 2023 and 1130 GWh in 2024. Curtailment which would be paid for to RES-E producers.

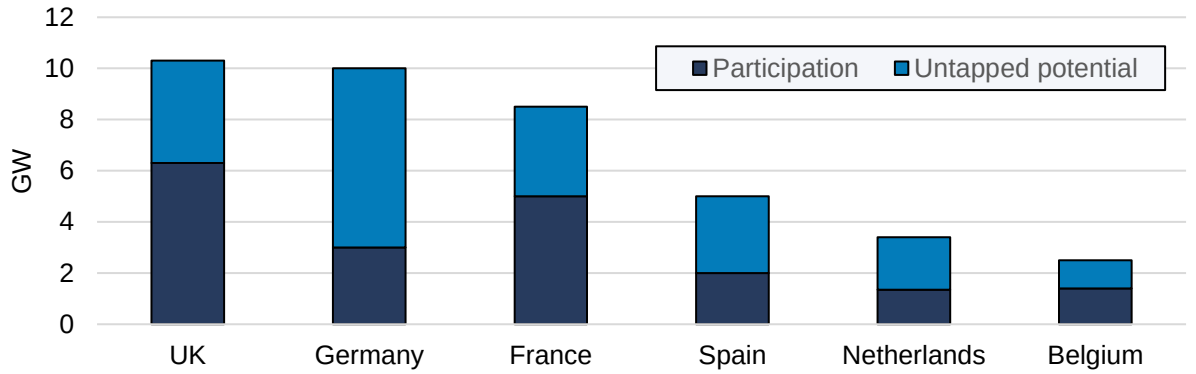
***Sources**: CL analysis based on ENTSOE and pv-magazine*
***Notes**: [1] Corresponds to a decrease in load corresponding to Metlen's current industrial baseload*

3 Industrial load flexibility has substantial potential to support efficient power system operations

Industrial load can in some sectors provide substantial flexibility to the EU power system as it decarbonises.

- Further industry electrification offers potential to scale up industrial load flexibility. By 2030, electricity could provide 50% of industry's final energy consumption including feedstocks (compared to 20% today).[1]
- SmartEn estimates that industrial demand response could reach 22 GW in 2030, representing 3% of EU's peak demand.[2]

Participation and untapped potential of industrial demand response (GW, 2020)[1]



Suitable markets and remuneration for industrial demand response

Market	Remuneration
Day-ahead market	Energy cost savings by optimising plant operation hours to avoid high price periods, thereby reducing load cost
Capacity market	Payments for being available in energy markets during periods of grid stress (periods with risk for security of supply)
Ancillary services	Reducing load with short-activation time in response to TSO signals for balancing consumption and generation near real-time
Interruptibility scheme	Payments for large industrials to curtail load when called, usually in rare occasion (5 to 25 times a year)

***Sources**: [1] Compass Lexecon (2024), Energy and climate transition: How to strengthen the EU's competitiveness ; [2] DNV, SmartEn (2022), Demand-side flexibility in the EU: Quantification of benefits in 2030*

3 Yet industrial flexibility potential is sector specific, with some core processes designed to be continuous

However, flexibility capabilities differ vastly between industrial processes

- The potential for flexibility in some industries including paper and pulp, food and beverages is significant, due to electrification solutions mostly comprising heat pumps and products being storable.
- However, some manufacturing sectors are facing technical and economical constraints for flexibility provision.
- For high temperature manufacturing industries, constraints vary but a range of solutions exist to ensure a flexible production process, provided the regulatory and economic framework provide the right incentives (see right Table).

	Source of flexibility	Flexibility capabilities	Constraints
Steel Electric Arc Furnaces	Interruption of the electric arc furnace (c. 80% of the load)	Short: Up to 1h, within 15min Long: For a few hours, within 1h	• Risk of solidification of the molten metal • Continuity of the casting sequence, can be slowed down but interruption is costly
Aluminium smelters	Complete interruptions of potline(s) or load reduction over several potlines	Up to 1h, within 5 min	• Risk of solidification of the melted aluminium bath • Deterioration of the electrolytic cells and power electronics equipment • Loss of efficiency of the electrolytic cells • Continuity of the casting sequence, can be slowed down but interruption is costly
Cement production	Interruptions of either the whole process or one flexible step (raw material preparation or cement milling)	Short: Up to 1h, within 15min Long: For a few hours, within 1h	• Clinker burning phase cannot be interrupted • Potential increase in maintenance cost if interruptions are frequent

***Notes**: Table was based on detailed interview sessions with experts in selected industries.*

3 Harnessing industrial flexibility's potential requires affordable electricity supply, electrification of processes and valuing flexibility adequately

I Securing Abundant Competitive Low-carbon Energy

- **Deliver abundant and competitive low-carbon energy supply**: boost low-carbon energy production, accelerate grid infrastructure development, accelerate flexibility development.
- **De-risk low-carbon electricity supply for large energy users**: boost development of power purchase agreements, long-term contracts and forward hedging, and support industrial renewable electricity self-consumption.
- **Implement exemptions from RES-E charges where relevant and cost-reflective network charges** to improve competitiveness of power purchases for electro-intensive industries.
- **Align energy taxation on climate goals**: revise tax levels on electricity to avoid incentives to use other energy carriers in industrial processes.

II Providing Cost-effective Investment and Operating Aid for electrification

- **Optimise the use of EU funds and State Aid using principles from carbon leakage mitigation framework**: provide investment aid (and where relevant operating aid) for electrification of energy- and carbon-intensive industries .
- **Revise the current framework to address international competitiveness in relation to energy costs and carbon leakage issues**: review existing EU funding and state aid compensation framework to support decarbonisation of industries facing international competitiveness issues and an unlevel playing field regarding energy and carbon costs.

III Boosting the deployment of flexibility in the power system *(industrial or else)*

- **Address barriers to the effective market participation of flexible resources in electricity market** and ensure stacking-up of revenues across markets. Allowing all types of resources to participate across all markets, and reform existing market eligibility and technical participation rules so that they do not constitute barriers to small-size distributed and energy storage assets.
- **Ensure that the market design adequately reflects the full value of flexibility for the power system** through the creation of markets and products addressing the full spectrum of power system needs and accounting for capabilities of flexible assets.
- **Where relevant, create a specific de-risking contractual and regulatory framework** to provide long-term predictability of revenues to flexible assets.

Sources: *Compass Lexecon (2024), Energy and climate transition: How to strengthen the EU's competitiveness ; Compass Lexecon (2024), Reviving Europe's Industrial Power: how to boost competitiveness through energy; CL analysis*

Contacts & Locations

Fabien Roques

Head of European Energy Practice

froques@compasslexecon.com

Florian Bourcier

Senior Economist

fbourcier@compasslexecon.com

Europe

Berlin
Brussels
Copenhagen
Düsseldorf
Helsinki
London
Madrid
Milan
Paris

North America

Boston
Chicago
Houston
Los Angeles
Miami
New York
Oakland
Washington, DC

Latin America

Buenos Aires
Santiago

Asia Pacific

Beijing
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