INVESTIGATION BY THE ENTSO-E EXPERT GROUP INTO THE IBERIAN BLACKOUT OF 28 APRIL 2025

Assessment of the investigation following the meeting on 23 June 2025

On 28 April 2025, at 11:33 a.m. (12:33 p.m. CEST), the power systems of Portugal and Spain experienced a blackout that also affected, for a very short period, a small area in France, close to the border with Spain. The rest of Continental Europe's electricity system did not suffer any significant disruption.

Following the blackout incident, on 12 May 2025, in accordance with European regulations, ENTSO-E (European Network of Transmission System Operators for Electricity) set up an Expert Panel to investigate the causes of the incident, produce a comprehensive analysis and make recommendations in a final report that will be published. The ENTSO-E Expert Panel has met three times so far. The last meeting was on 23 June 2025.

The Expert Panel consists of representatives from the Transmission System Operators (TSOs), the Agency for the Cooperation of Energy Regulators (ACER), the National Regulatory Authorities (NRA's), including ERSE, and the European Regional Coordination Centres (RCCs).

This Panel is led by experts from TSO's not directly affected by the incident and includes 45 experts from both affected and non-affected TSO's from various European countries.

All the up-to-date information on the incident can be consulted on the European Network of Transmission System Operators for Electricity website created for this purpose. This page serves as a central source for updates on the blackout investigation. The information published is based on preliminary analyses by the Expert Panel and is subject to change at any time as the investigation progresses.

1. WHAT ARE THE STEPS OF THE INVESTIGATION?

The Expert Panel began its investigation into the causes of the blackout on 12 May 2025.

The investigation, according to the ENTSO-E is conducted in two phases:

i. **Collecting data for the factual report:**

In the first phase of the investigation, the Panel of Experts is collecting and analysing all available data on the incident in order to reconstruct the events of 28 April and determine the causes of the blackout.

To this end, the Panel has received information from all the TSOs affected and has also requested information from Red Eléctrica and the Spanish authorities, having already received data from 32 organisations. At the end of this first phase, and after evaluating the data provided, the Panel of Experts will deliver a first factual report to present the facts and data about the incident. Although the legal deadline for producing this report is 28 October 2025, six months after the incident, the Panel of Experts intends to deliver it earlier.

ii. **Recommendations for the Final Report:**

In the second phase, the Panel of Experts will perform a detailed analysis and will establish recommendations to help prevent similar incidents in the future, which will be published in the final report. The final report is expected to be delivered 2 to 3 months after the factual report. This report will be published and presented to the European Commission and the Member States via the Electricity Coordination Group.

The ENTSO-E points out that carrying out a rigorous, fact-based analysis of incidents of this magnitude and technical complexity takes time. In particular, it involves a detailed reconstruction of the precise operation of the Iberian, French and European electricity system in general in the hours leading up to the blackout. This approach is in line with the Incident Classification Scale Methodology (ICS Methodology), developed in accordance with Regulation (EU) 2019/943 on the internal electricity market and Commission Regulation (EU) 2017/1485 laying down guidelines for the operation of the electricity transmission system (SO GL). The ICS Methodology establishes the framework for reporting and classifying incidents in the electricity system and for organising the investigation of extensive and major incidents.

2. WHAT IS KNOWN SO FAR?

According to the data collected by the ENTSO-E, the blackout resulted from a complex sequence of events.

After its third meeting, on 23 June 2025, the Panel of Experts, in its analysis of the conditions of the electricity system before the incident, found that during the morning of 28 April there were significant variations in voltage and frequency and that, immediately before the incident, there were initial production trips, with the voltage reaching values that exceeded the operational limits in a large part of the Spanish transmission network, which eventually led to the blackout.

Based on the information currently available, the Panel of Experts has established a preliminary chronology of the incident. This chronology will be updated and complemented with additional information as the investigation progresses.

3. CHRONOLOGY OF EVENTS

A preliminary chronology, based on the information known so far by ENTSO-E, has been identified regarding the complex sequence of events, which have occurred prior to the blackout.

i. System conditions on the morning of 28 April (09:00 - 12:00 CEST)

During the night of 27 to 28 April, the Iberian power system operated normally, with no significant variations in the voltage profile. From approximately 9:00 am (CEST - Central European Summer Time), voltage variability in Spain started increasing, but without significant variations until 10:30 am (CEST). From 10:30 am (CEST), more significant voltage variations started to occur.

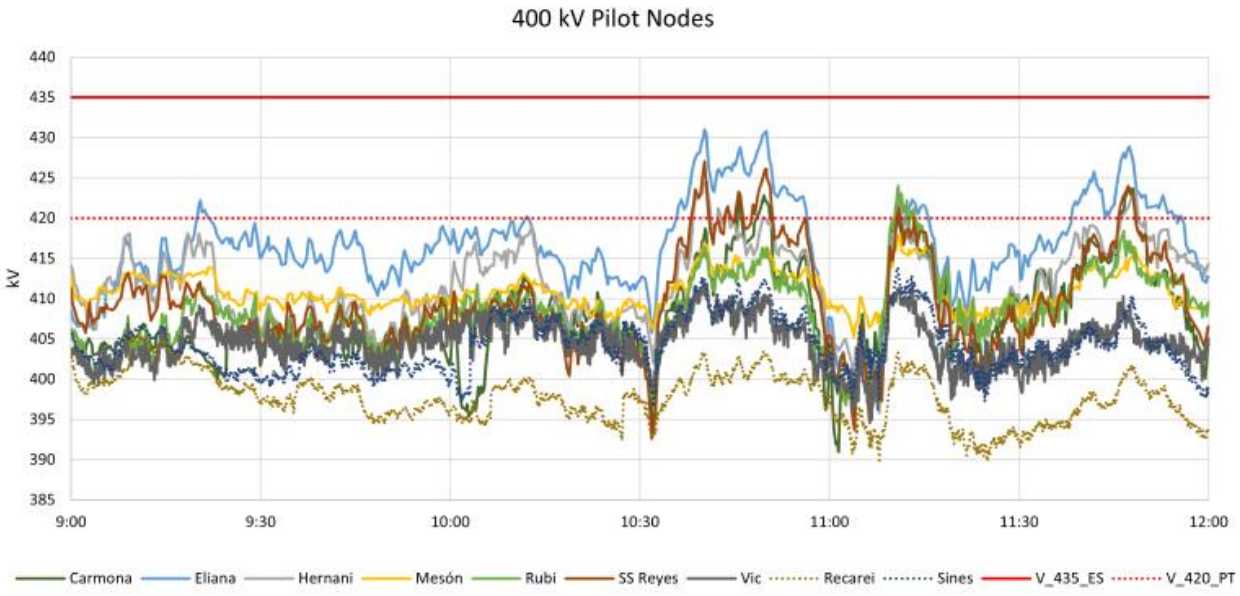

Figure 2a - Voltage evolution from 9am to 12pm CEST at the main 400 kV transmission substations in Spain and Portugal. 420 kV is the maximum permissible value in Portugal (red dotted line), while in Spain it is 435 kV (plain red line), in accordance with Commission Regulation (EU) 2017/1485 establishing guidelines for the operation of electricity transmission systems. [source: Telemeasurements every 4'' from Red Electrica and REN]

Figure 3 - Location of substations where voltage measurements were taken

ii. System conditions prior to the incident (12:00 - 12:30 CEST)

During the half hour preceding the blackout, two main periods of oscillations (power and frequency swings) were observed in the Continental Europe Synchronous Area.

The first occurred between 12:03 and 12:07 CEST. Preliminary analysis of the available information indicates that this was a forced local oscillation (i.e. induced by an external source), with a dominant frequency of 0.64 Hz, primarily affecting the Spanish and Portuguese power systems.

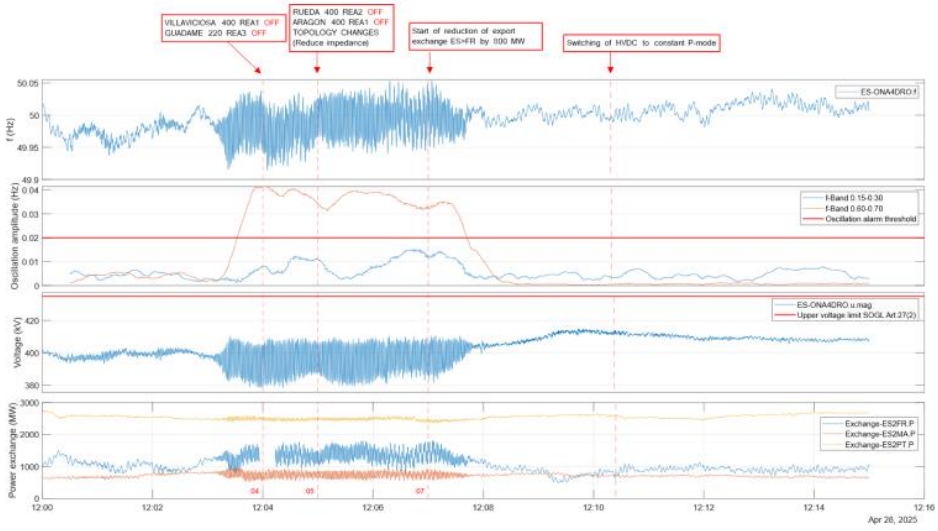

Figure 5 - Characteristic data of the first oscillations (source: WAMS sampling rate 100 ms at the 400 kV Carmona substation) and countermeasures

After these first oscillations, the operating mode of the direct current (HVDC) interconnector between Spain and France was changed to fixed power from 12:11 CEST, as a mitigation measure to stabilise the system. Other additional measures were taken, such as *shunt* reactors manoeuvres, topological changes to minimise system impedance, to try to stabilise the system.

The second oscillation occurred between 12:19 and 12.22 CEST. This was an inter-area oscillation, with a dominant frequency of 0.21 Hz, corresponding to the well-known East-Centre-West continental mode.

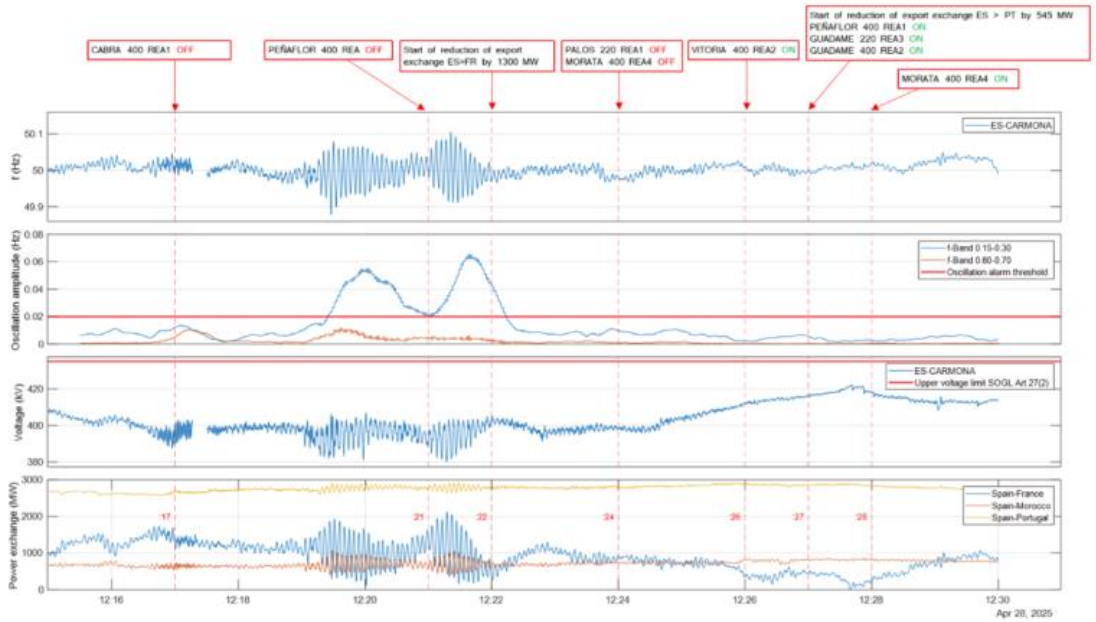

Figure 6 - Characteristic data of the second oscillation and voltage increase (source: WAMS sampling rate of 100 ms at the 400 kV Carmona substation) and countermeasures

This second oscillation was effectively mitigated through countertrading measures, which reduced power flows between France and Spain, also with the coupling of internal power lines in southern Spain.

Following the second oscillation, the voltage remained in the 390-420 kV range, before increasing again, but still within the operational voltage range on the Spanish transmission network. During this period, Spain's scheduled international exchanges - all in the export direction - were 1,000 MW to France, 2,000 MW to Portugal and 800 MW to Morocco.

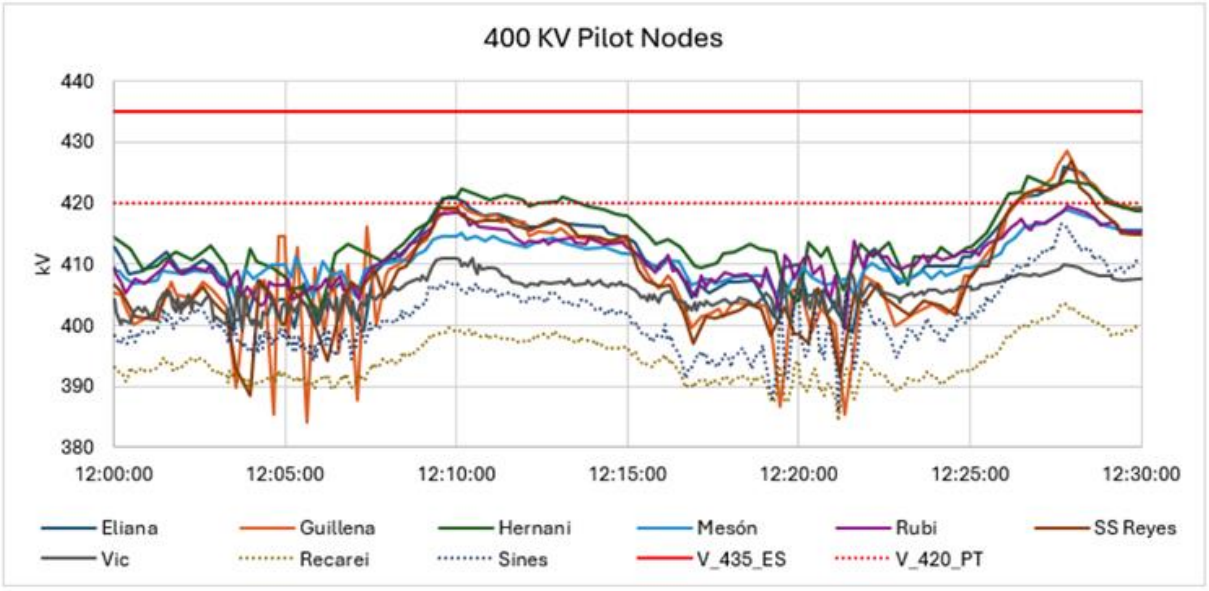

Figure 7a - Voltage evolution from 12:00 to 12:30 CEST at the main 400 kV transmission substations in Spain and Portugal. [source: Telemeasurements every 4'' by Red Eléctrica and REN]

iii. Sequence of events during the incident

The data currently available indicates the following sequence of events during the incident:

- At 12:32:57, 12:33:16 and 12:33:17 CEST

Production shutdowns were observed in the Granada, Badajoz and Seville regions, totalling an initial estimate of 2,200 MW. No shutdowns were observed in Portugal or France during this period. As a result of these events, a voltage increase was observed in Spain, leading to a similar increase in Portugal as well, and the frequency decreased.

- Between 12:33:18 and 12:33:21 CEST

The voltage in the southern region of Spain increased dramatically and, consequently, also in Portugal. The over-voltage triggered cascading production losses, which caused the frequency of the Spanish and Portuguese power system to drop.

- At 12:33:19 CEST

The power systems in Spain and Portugal began to lose synchronisation with the European System.

- Between 12:33:19 and 12:33:22 CEST

The automatic load shedding and System Defence Plans of Spain and Portugal, elaborated in accordance with Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation (SO GL), were activated but failed to prevent the collapse of the Iberian power system.

- At 12:33:21 CEST

The Alternate Current overhead lines between France and Spain were disconnected by protection devices against loss of synchronism.

- At 12:33:24 CEST

All system parameters of the Spanish and Portuguese electricity system collapsed, and the direct current interconnector between France and Spain stopped transmitting power.

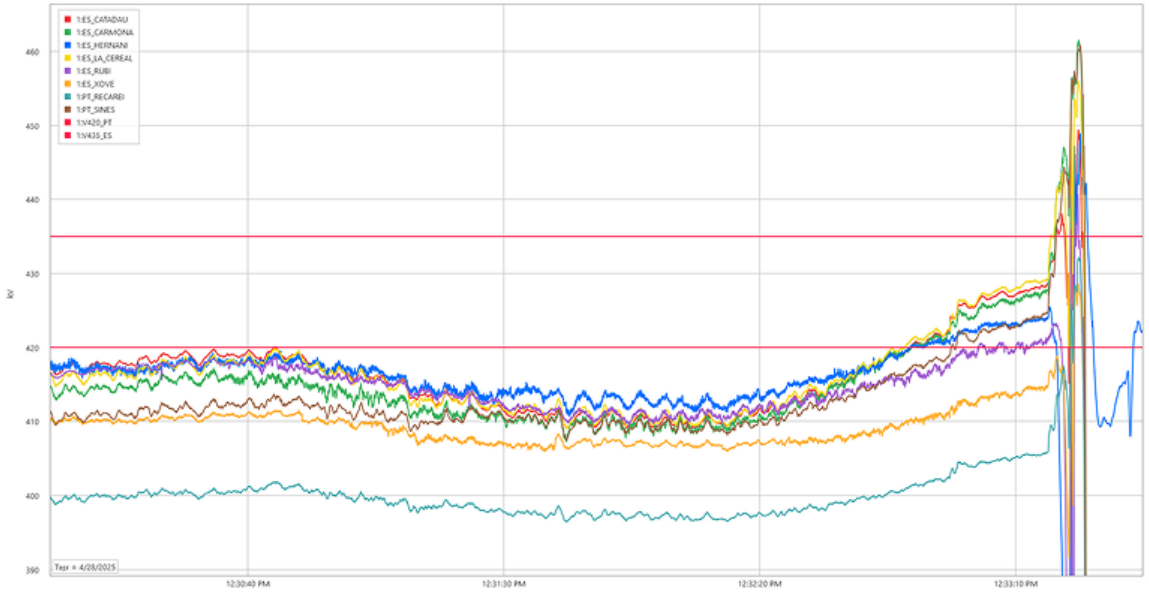

Figure 10a - Voltage evolution after 12:30 CEST at the main 400 kV transmission substations in Spain and Portugal. [source: PMU data from Red Eléctrica and REN]

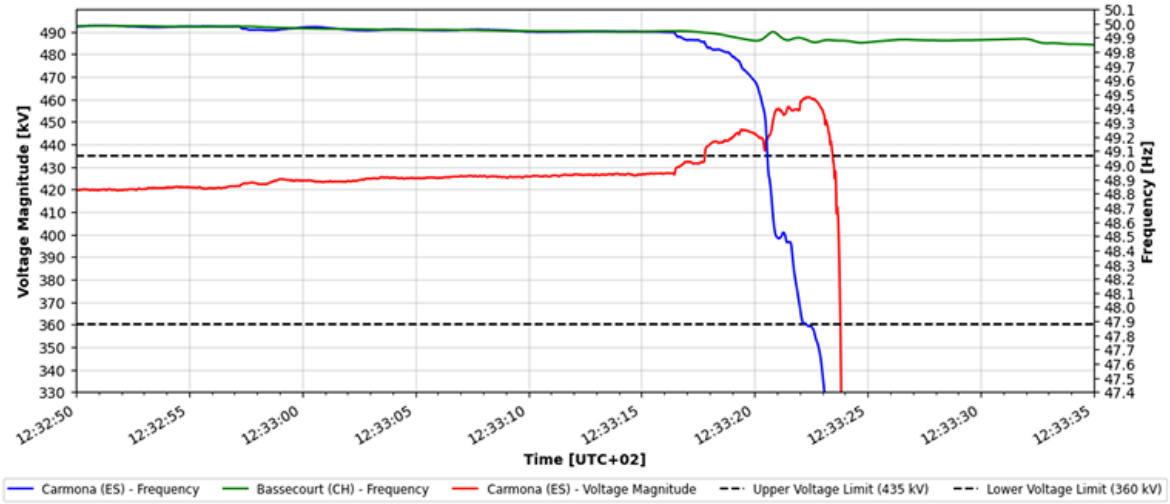

Figure 11 - Evolution of frequency and voltage at the Carmona substation (Spain) and frequency in the rest of continental Europe (Bassencourt substation, Switzerland) during the incident (sources: Red Eléctrica, Swissgrid)

4. RESTARTING THE SYSTEM

Following the incident, the TSOs affected, in the case of Portugal, REN, immediately activated their power system recovery plans.

The restart of the power system in some regions of Portugal and Spain was facilitated, among other things, by black-start processes in some power plants, as well as by the existing interconnections with France and Morocco.

In Portugal, the system was restarted by two power plants with autonomous Blackstart capacity: Castelo de Bode (hydroelectric power plant) and Tapada do Outeiro (combined cycle gas turbine plant).

According to ENTSO-E the rapid restoration of supply in Spain and Portugal demonstrated the preparedness and efficiency of the affected transmission system operators, Red Eléctrica and REN, with the support and collaboration of the French transmission system operator RTE and the Moroccan utility company ONEE. This was possible by the joint work and cooperation of the transmission system operators developed over the years, both between the control centres and within ENTSO-E.

In addition, the real-time monitoring and coordination of the status of the European electricity systems was achieved by the European Awareness System platform, a tool developed by all TSOs within ENTSO-E.

The main steps undertaken by the TSOs for the restoration process were as follows:

- At 12:35 and 12:43 CEST

REN requested black-start mode start-ups for the Castelo de Bode hydropower plant and the Tapada do Outeiro combined cycle gas turbine power plant.

- At 12: 44pm CEST

A first 400 kV line between France and Spain was re-energised (Western part of the border).

- At 12: 45 CEST

The hydropower plant of Castelo do Bode, operating in black-start mode, connected to the 220 kV of the neighbouring REN substation.

- At 13:04 CEST

The interconnection between Morocco and Spain was re-established.

From the start of the restoration until approximately 13:30 CEST several hydropower plants in Spain with black-start capacity began their autonomous start-up processes to restart the system.

- At 13:35 CEST

The Eastern part of the France-Spain interconnection was re-energised.

- At 16:11 CEST and 17:26 CEST

REN had established two restoration islands and was progressing and rapidly restoring the supply of demand in these regions, using the Castelo de Bode hydropower plant and the Tapada do Outeiro combined cycle gas turbine power plant.

- At 18:36 CEST

The first 220 kV tie-line between Spain and Portugal was re-energised, speeding up the recovery of the Portuguese system.

- At 21:35 CEST

The Southern 400 kV tie-line between Spain and Portugal was re-energised.

- At 00:22 CEST on 29 April 2025

The restoration process of the transmission grid was completed in Portugal.

- At around 04:00 CEST

The restoration process of the transmission grid was completed in Spain.

The following figures indicate the evolution of consumption and the generation mix in Spain and Portugal before the blackout, during and after the restoration process.

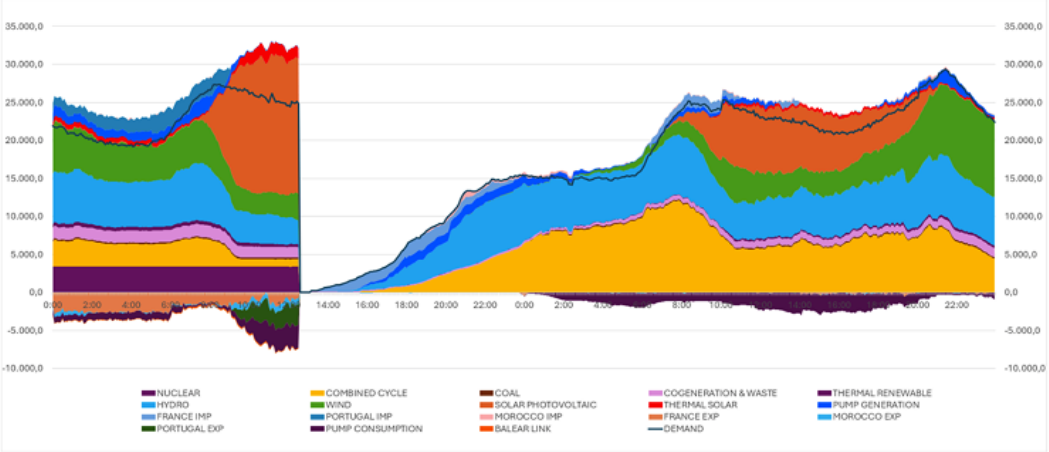

Figure 12a - Generation and consumption mix in Spain on 28 and 29 April

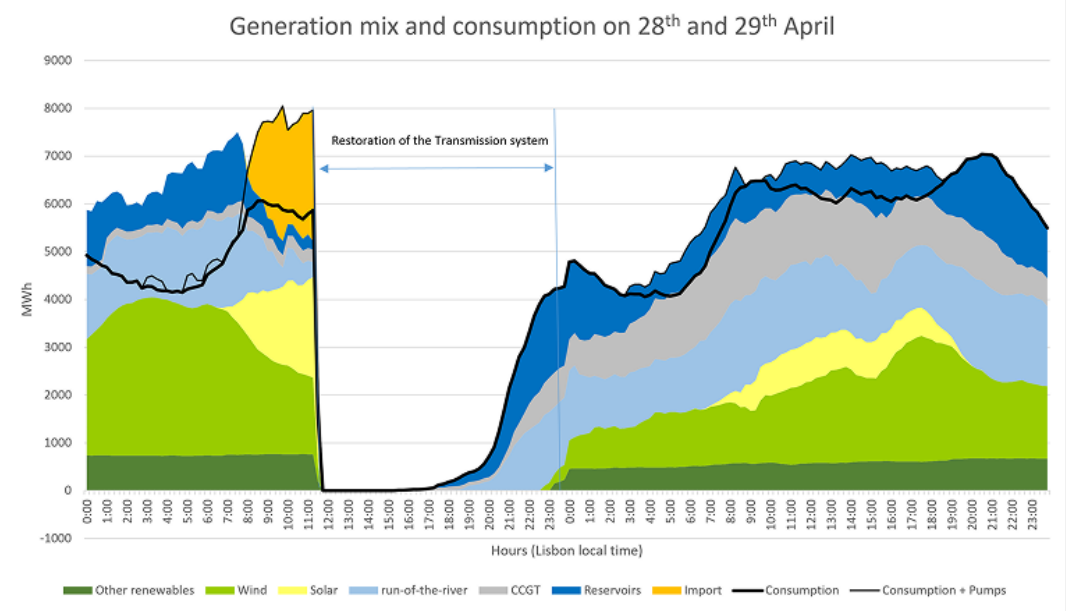

Figure 12b - Generation and consumption mix in Portugal on 28 and 29 April

Lisbon, 30 th June 2025