

Operation of the Power Systems of Madeira and Porto Santo Islands

2nd Isolated Electrical Systems Congress

Tenerife, 15 October 2026



Consejería Insular de Industria, Comercio,
Sector Primario y Bienestar Animal
Consejería de Industria



Electricidade
da Madeira

Diogo Vasconcelos

Innovation & European Projects Manager at EEM-
Empresa de Electricidade da Madeira, S.A.

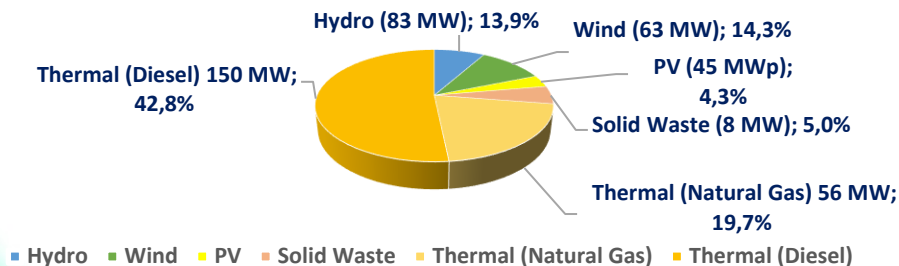
EEM – Empresa de Electricidade da Madeira, S.A. (Electricity Generation, TSO, DSO, Supplier)

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YEAR 2025 DATASET

AUTONOMOUS REGION OF MADEIRA

Power Generation Mix – 2025 – Madeira Island



Islands' RE Targets:

→ 50% RES by 2027/28

→ ≥ 55% RES by 2030

Total Installed Power ≈ 405 MW

Peak Demand ≈ 168,39 MW (31/12 – 20h00)

Total EE emission to the grid ≈ 938,61 GWh

Population ≈ 246 000 inhabitants*

Area: 741 km²

TOTAL POPULATION ≈ 250 744 inhabitants

MADEIRA ISLAND

Share of RES in
Madeira: 37,5%

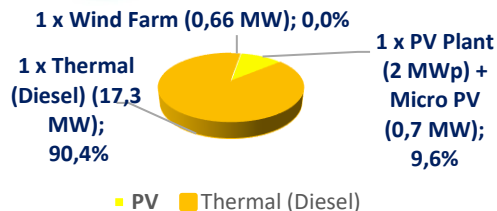
Source: EEM

EEM's Employees: 634

PORTO SANTO ISLAND

Share of RES in
Porto Santo: 9,6%

Power Generation Mix – 2025 Porto Santo Island



Total Installed Power: 20,7 MW

Peak Demand ≈ 7,60 MW (22/08 – 21h00)

Total EE emission ≈ 37,05 GWh

Population ≈ 5 151 inhabitants*

Area: 42,48 km²

*(Source: Census 2021)

EEM Clients ≈ 145 213 Madeira | 5 101 Porto Santo

Merit Order Dispatch

Core Operating Strategy:

1. Ensure power system security and reliability
2. Maintain spinning reserve $\geq$ the capacity of the largest generating unit or generator cluster online
3. Maximise RES integration

Merit Order:

Without Strategic Assets (Past):

With Strategic Assets (Present / Future)

a) Firm Thermal Capacity

Minimum 4 generator sets

Towards “0” thermal generation

b) Run-of-River Hydropower

Run-of-river hydro

Idem

c) Solid Waste-to-Energy

Solid waste

Idem

d) Solar PV Generation

PV Generation

Idem

e) Wind Generation

Wind farms

Idem

f) Hydropower Peak Shaving and Balancing

Peak shaving with Hydropower

Idem

g) Additional Thermal Generation (if required)

Additional Thermal Generation (if required)

Idem

EEM – MADEIRA and PORTO SANTO

Grid Code (2019)

Requirements	Installation type				
	A Esp. < 2.5 kW	A < 100 kW	B < 1 MW	C < 5 MW	D > 5 MW
Steady-state operation requirements					
1-Acceptable frequency range	X	X	X	X	X
2-Acceptable voltage range	X	X	X	X	X
3-Range of injection and reactive power consumption			X	X	X
4-Voltage control		X	X	X	X
5-Remote control of the operating point			X	X	X
Dynamic regime operation requirements					
6-Survival of frequency gradients (Δf up to 4 Hz/s)	X	X	X	X	X
7-Frequency variation sensitivity mode – overfrequency (LFSM-O)		X	X	X	X
8-Frequency Variation Sensitivity Mode (LFSM)				X	X
9-Ride through capability			X	X	X
10-Active power recovery after voltage dips			X	X	X
11-Capacity for dynamic control of reactive current during overvoltages			X	X	X
12-Capacity for dynamic control of active and reactive current during voltage dips				X	X
13-Active power recovery ramps				X	X

grid code Madeira	
<i>Gama de frequência</i>	<i>Período de tempo</i>
$52 \text{ Hz} \leq f < 53 \text{ Hz}$	$\Delta t \geq 20 \text{ s}$
$47,5 \text{ Hz} < f < 52 \text{ Hz}$	Δt ilimitado
$47 \text{ Hz} < f \leq 47,5 \text{ Hz}$	$\Delta t \geq 20 \text{ s}$

Taxa de variação máxima a suportar**	até $\pm 4 \text{ Hz/s}$ $\Delta t: 250 \text{ ms}$
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** exceto A especial

EEM – MADEIRA ISLAND (PORTUGAL)

System Services in non-interconnected electrical systems

Capabilities to ensure the safe operation of the electric system:

- **A-** Inertia capability
- **B-** Frequency regulation capability:
 - **B1-** Primary regulation
 - **B2-** Secondary regulation
- **C-** Voltage control/regulation capability
- Short-circuit capacity

Critical issue: high values of df/dt (RoCoF)



Traditional mix system generation		System services		
Technology	A-Inertia	B1_Frequency primary regulation	B1_Frequency secondary regulation	C-Voltage regulation
Thermal Generation (Gas, Fuel/Diesel engines)	X	X	X	X
Hydro	x	-	x	X
Wind	x	-	-	x
PV	-	-	-	x
Waste incineration	X	-	-	x
Result	X ✓	X ✓	X ✓	X ✓
Result without thermal generation	x	-	x	X ✓

Mix system generation, without thermal		System services		
Technology	A-Inertia	B1_Frequency primary regulation	B1_Frequency secondary regulation	C-Voltage regulation
Synchronous condenser with inertia	X			X
Battery Power Plant	-	X	X	X
Hydro reversible (Storage, pumping and operation as a synchronous condenser)	x	-	X	X
Wind	x	-	-	x
PV	-	-	-	x
Waste incineration	X	-	-	x
Result without thermal generation	X ✓	X ✓	X ✓	X ✓

EEM's ENERGY STORAGE ASSETS: Reversible Hydro Power

Socorridos Reversible Hydroelectric Power

Plant Installed Power: 24,0 MW

Pumping Inst. Power: 3 x 3,75 MW

Initial Operation: 1994 → 2006
(Reversible)



Source: EEM

***Also acts as:
Synchronous
Condenser**

Calheta III Reversible Hydroelectric Power

Plant Installed Power: 30,0 MW

Pumping Inst. Power: 3 x 5,5 MW

Initial Operation: 2021

Source: EEM



***Also acts as:
Synchronous
Condenser**

EEM's Hydro Power Plant	Reversible Hydroelectric System Water Reservoirs					
	VOLUME (m³)		Head (m)	Power (MW)		
	Total	Useful		Production	Pumping System	Energy (MWh)
Socorridos	40 000	30 000	457	24	10	30
Calheta III*	1 000 000	860 000	650	30	17	1 273
Pumping*	70 000	65 000				100

EEM's ENERGY STORAGE ASSETS:

BESS Porto Santo I

Nominal Power: 5,4 MVA / 4,3 MW

Capacity (BoL): 3,3 MWh (DC)

Provisional Acceptance: 06/2020



Source: EEM

Eligible Total Cost: 3.576.843,12 €

EU Financial Support: 641.958,64 €

Co-financed by POSEUR
(Cohesion Fund):



REGIÃO AUTÓNOMA
DA MADEIRA



UNIÃO EUROPEIA
Fundo de Coesão

BESS Madeira I – Vitória

Nominal Power: 23,7 MVA / 16,4 MW

Capacity (BoL): 16,4 MWh (DC)

Provisional Acceptance: 09/2022

Eligible Total Cost: 9.308.857,27 €

EU Financial Support: 7.788.276,32 €



Source: EEM

EEM's ENERGY STORAGE ASSETS:

BESS Porto Santo II

Nominal Power: 12 MVA / 8,9 MW

Capacity (BoL): 18,6 MWh (DC)

Provisional Acceptance: 06/2024



Total Cost (Investment): 12.354.688,14 €

EU Financial Support: ≈ 11.000.000,00 €

Financed by Portugal's Recovery and Resilience Plan (PRR):



REGIÃO AUTÓNOMA
DA MADEIRA



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BESS Madeira II – Caniçal*

Nominal Power: 27 MVA / 24 MW

Capacity (BoL): 20,5 MWh (DC) + 6,8 MWh (DC)

Provisional Acceptance: 01/2025 + 06/2026

Total Cost (Investment): ≈ 18.100.000,00 €

Actual EU Financial Support: ≈ 18.000.000,00 €



Source: Hitachi Energy Portugal | EEM

* With Expansion

BESS IN THE MADEIRA ARCHIPELAGO +IMPACT

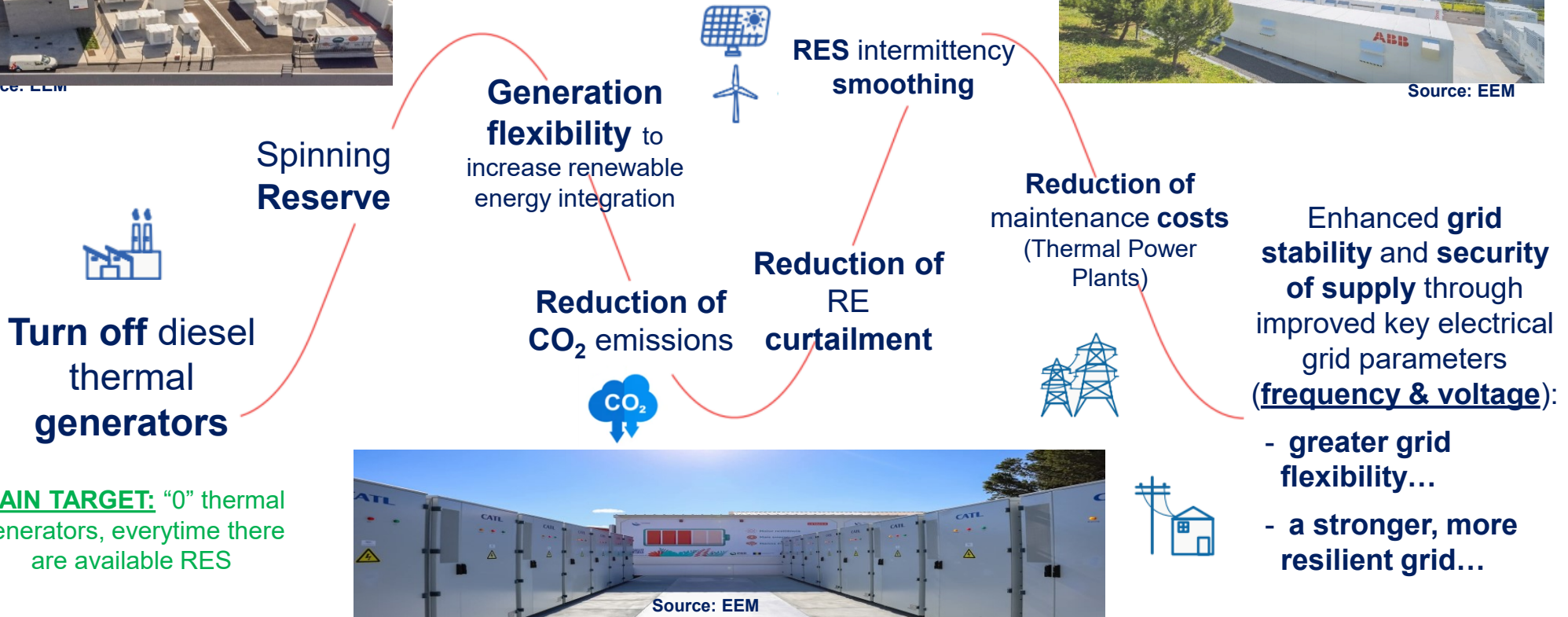


Source: EEM



Source: EEM

ENERGY TRANSITION



EEM's OTHER STRATEGIC ASSET: Synchronous Condenser* (Madeira Island)

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± 15 Mvar | (H) 10 s $\leftrightarrow$ Base: 10 MVA

(provides: short-circuit power and natural inertia + voltage regulation ($\uparrow$ % RES))



Financed by Portugal's Recovery and Resilience Plan (PRR):

*** Started Full Operation: July 2025**

Source: EEM

EEM's MOST VALUABLE ASSET: Human Resources (HR)

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31/12/2025

Source: OE Região Madeira



Source: DN Madeira



#634
Total
Employees



Source: EEM

#582
Employees in
Madeira
Island

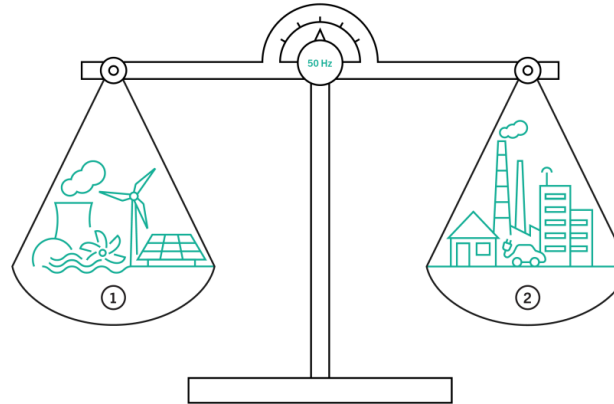
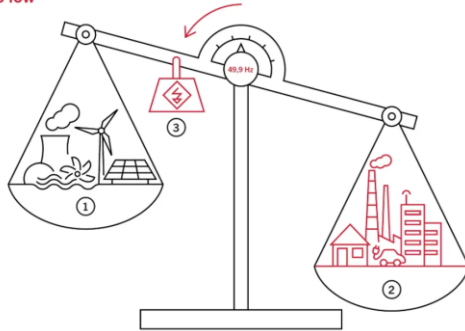
IMPACT AND RESULTS I

Madeira and Porto Santo BESS

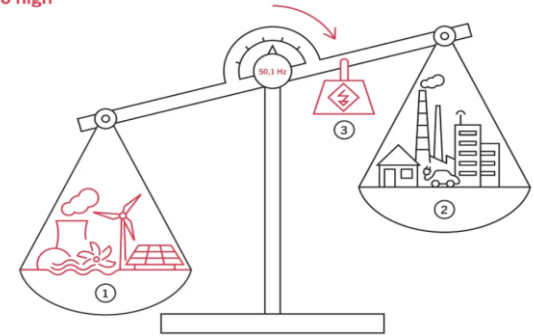
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Nominal frequency of 50 Hz

Frequency too low



Frequency too high



- 1 Generators/power plants
- 2 Consumers: private households and industry
- 3 Control energy

Source: <https://www.swissgrid.ch/en/home/operation/regulation/frequency.html>



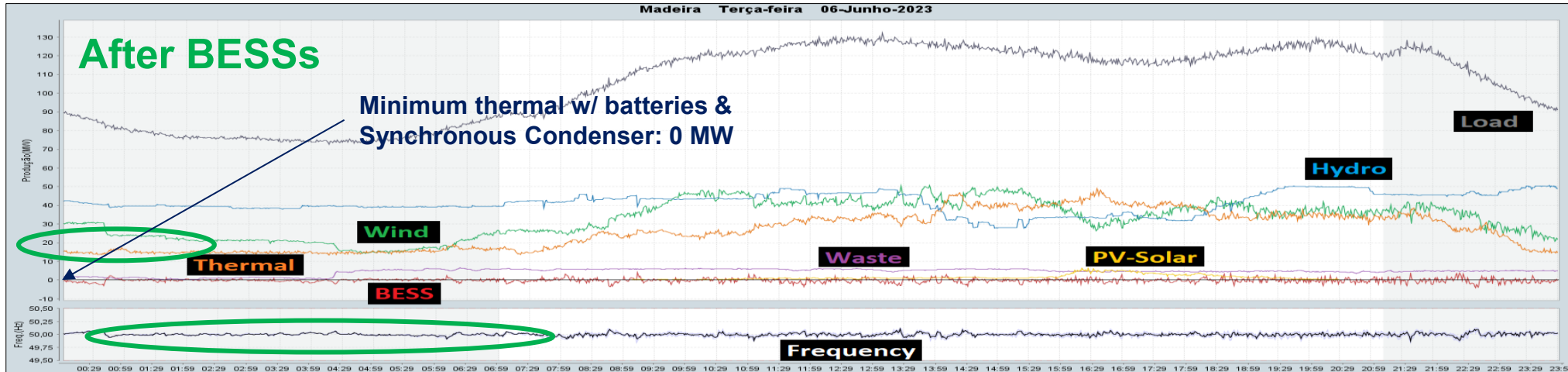
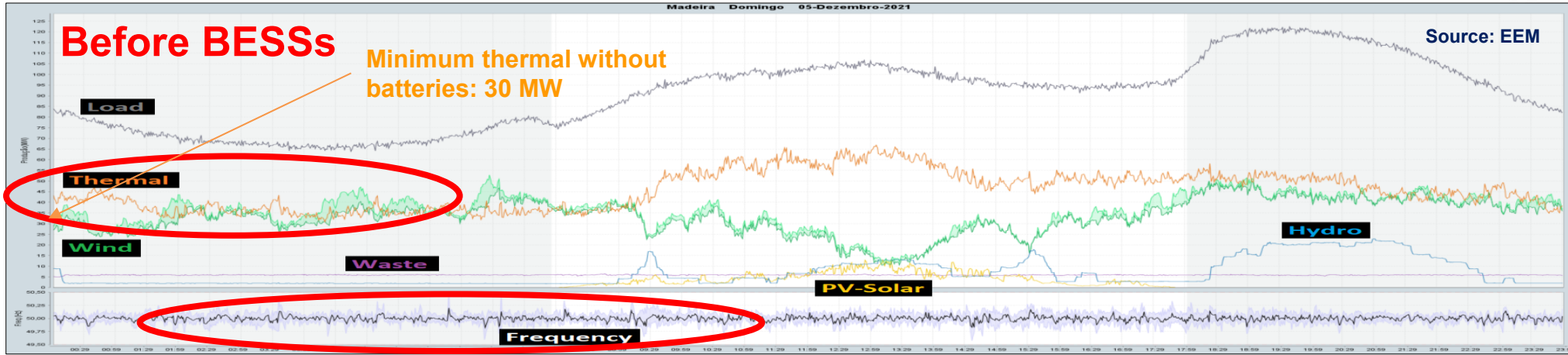
Source: EEM

- ✓ Substantial reduction of frequency variation achieved
- ✓ Substantial improvement in the quality of service provided to EEM customers

IMPACT AND RESULTS II

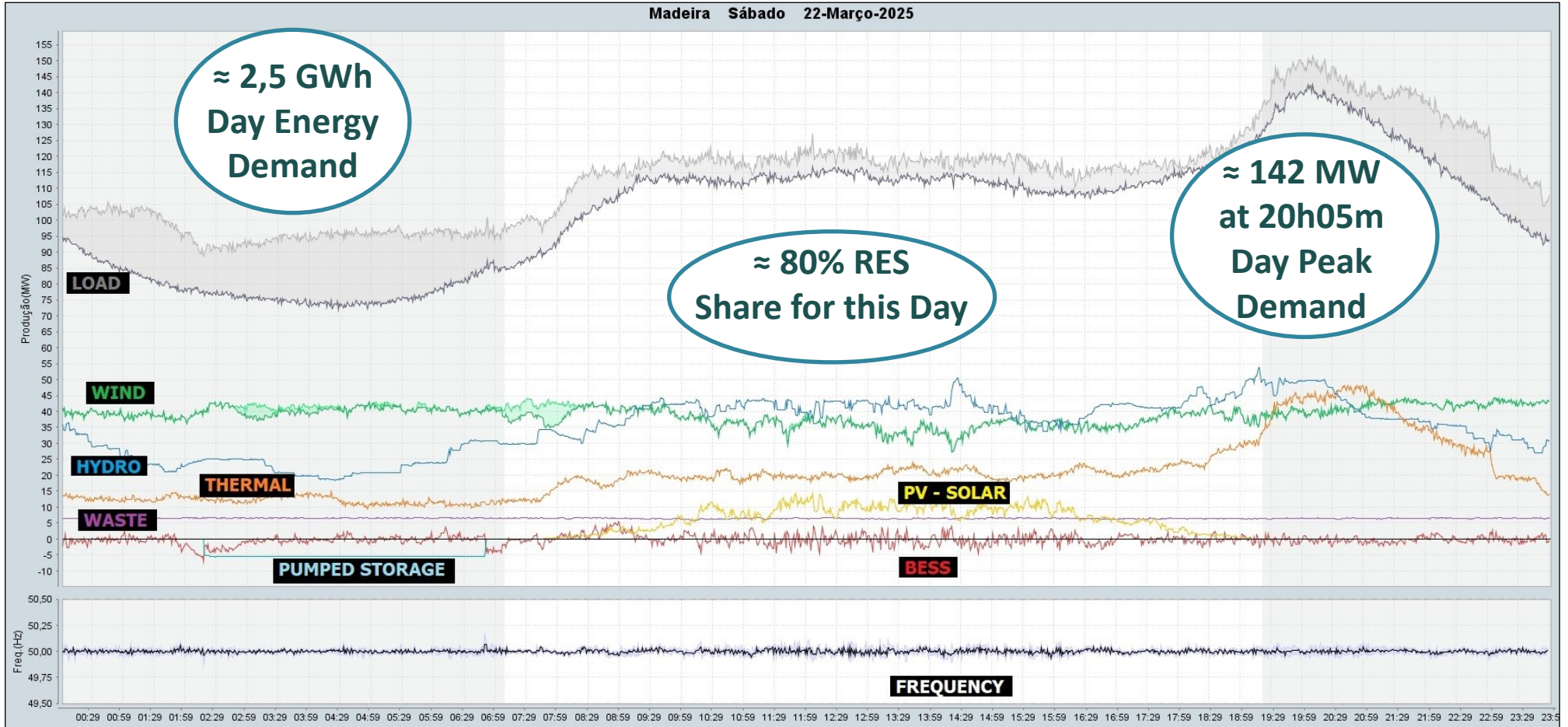
Madeira Island Load Diagram

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IMPACT AND RESULTS III

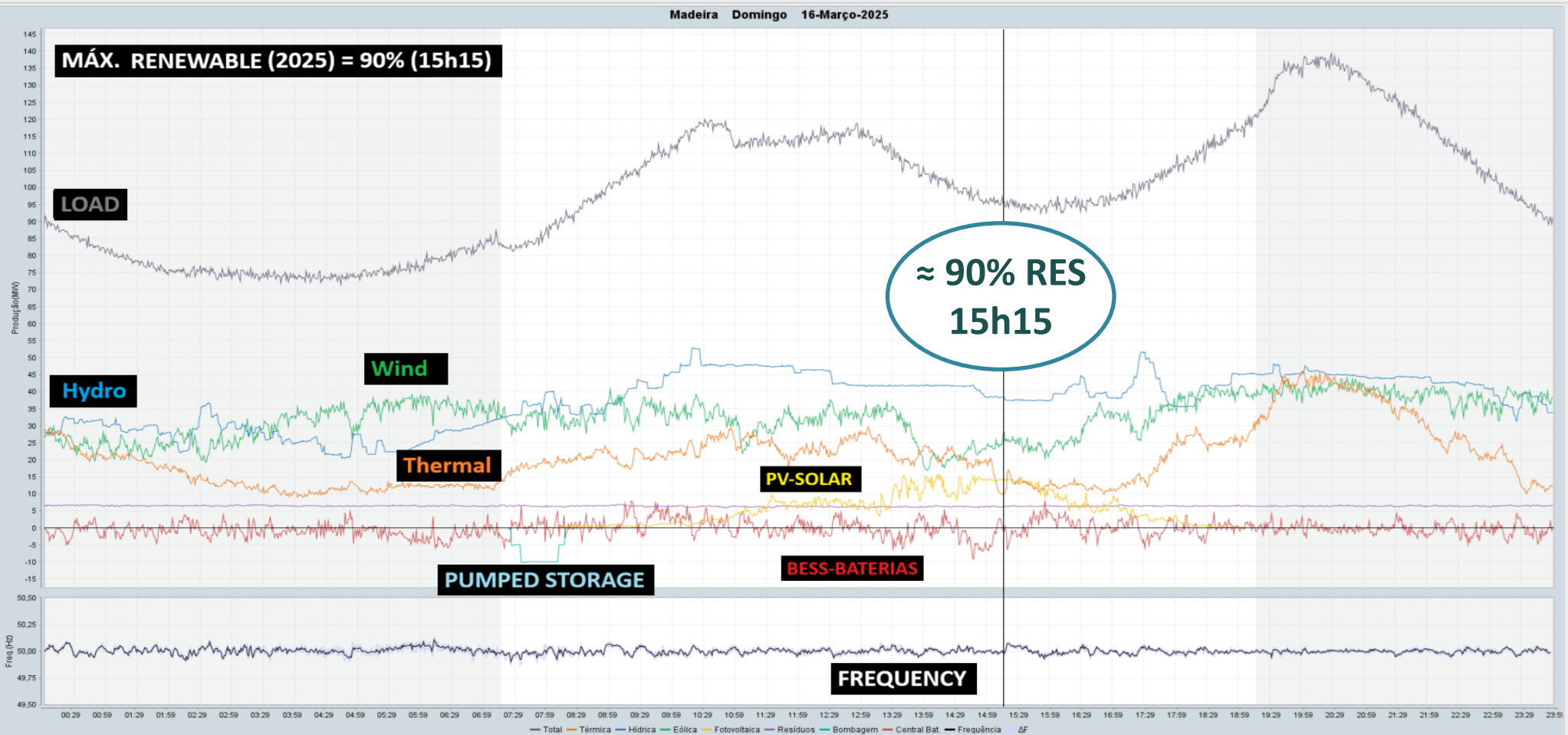
Madeira “Amazing Day” Load Diagram



IMPACT AND RESULTS IV

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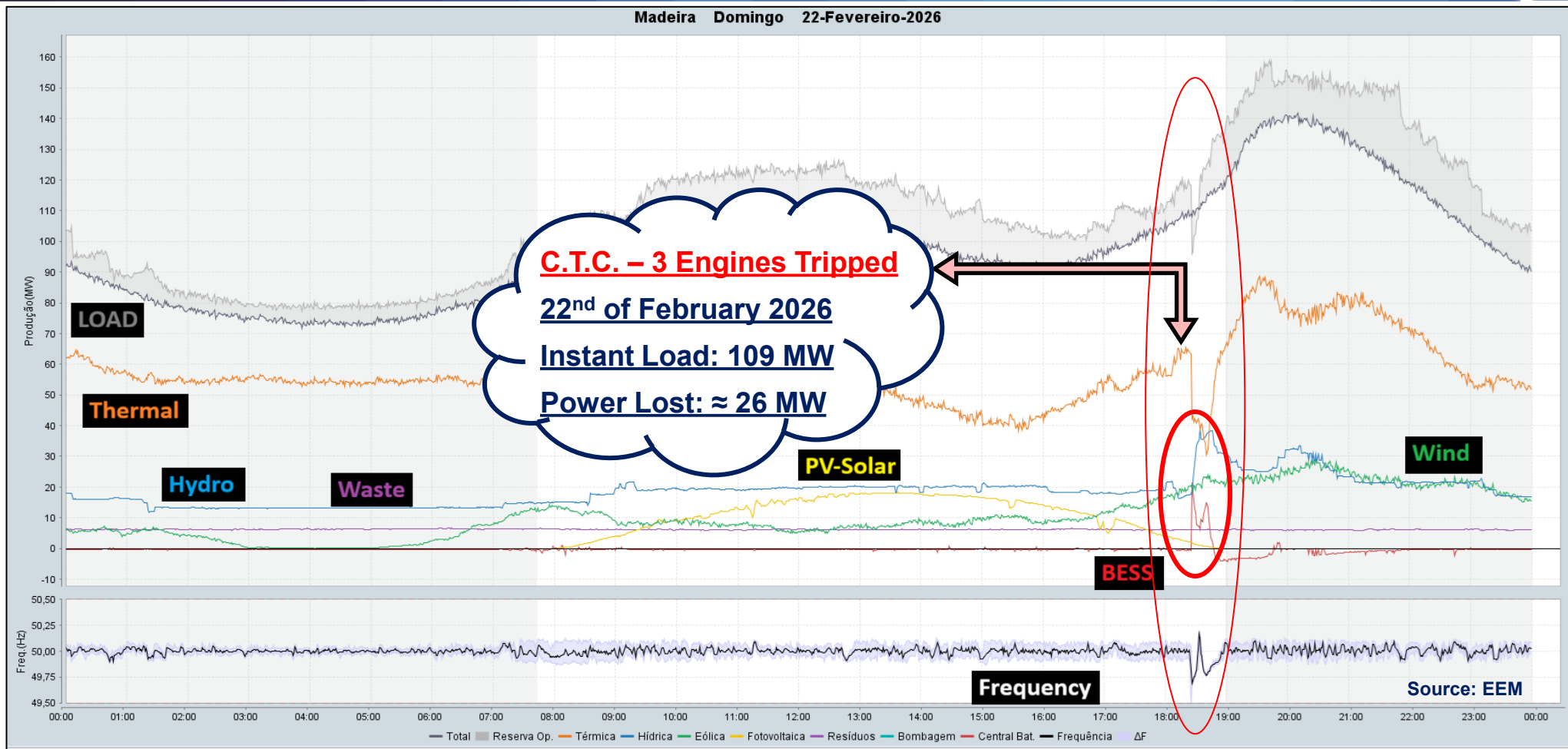
Madeira Load Diagram | Max. Instantaneous Renewable Penetration in the Grid



OTHER IMPACT & PRACTICAL OUTCOMES

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BESS Madeira I – Vitória + BESS Madeira II - Caniçal



OTHER IMPACT & PRACTICAL OUTCOMES

II Congresso Sistemas Eléctricos Aislados Tenerife 2026

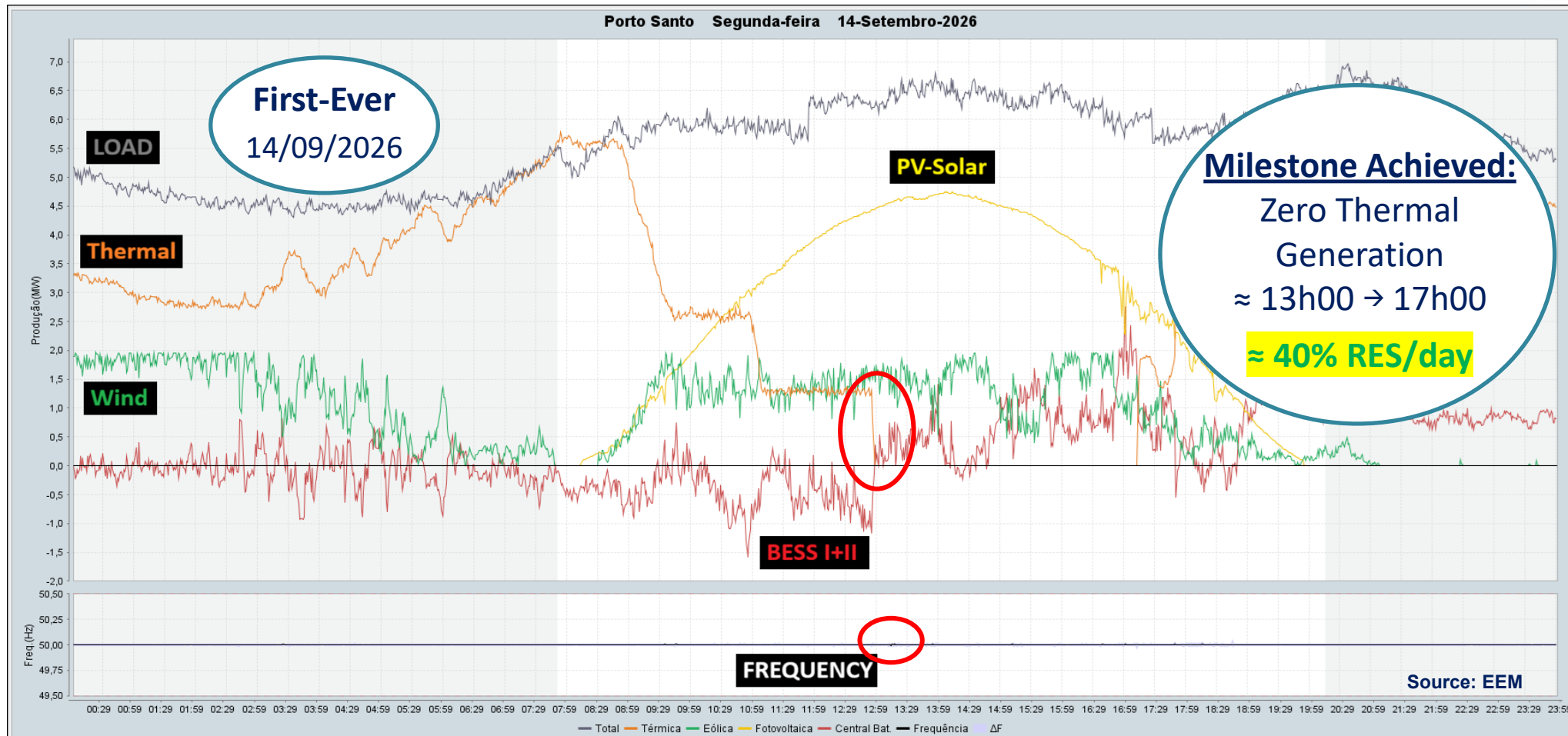
BESS Porto Santo I + II



OTHER IMPACT & PRACTICAL OUTCOMES

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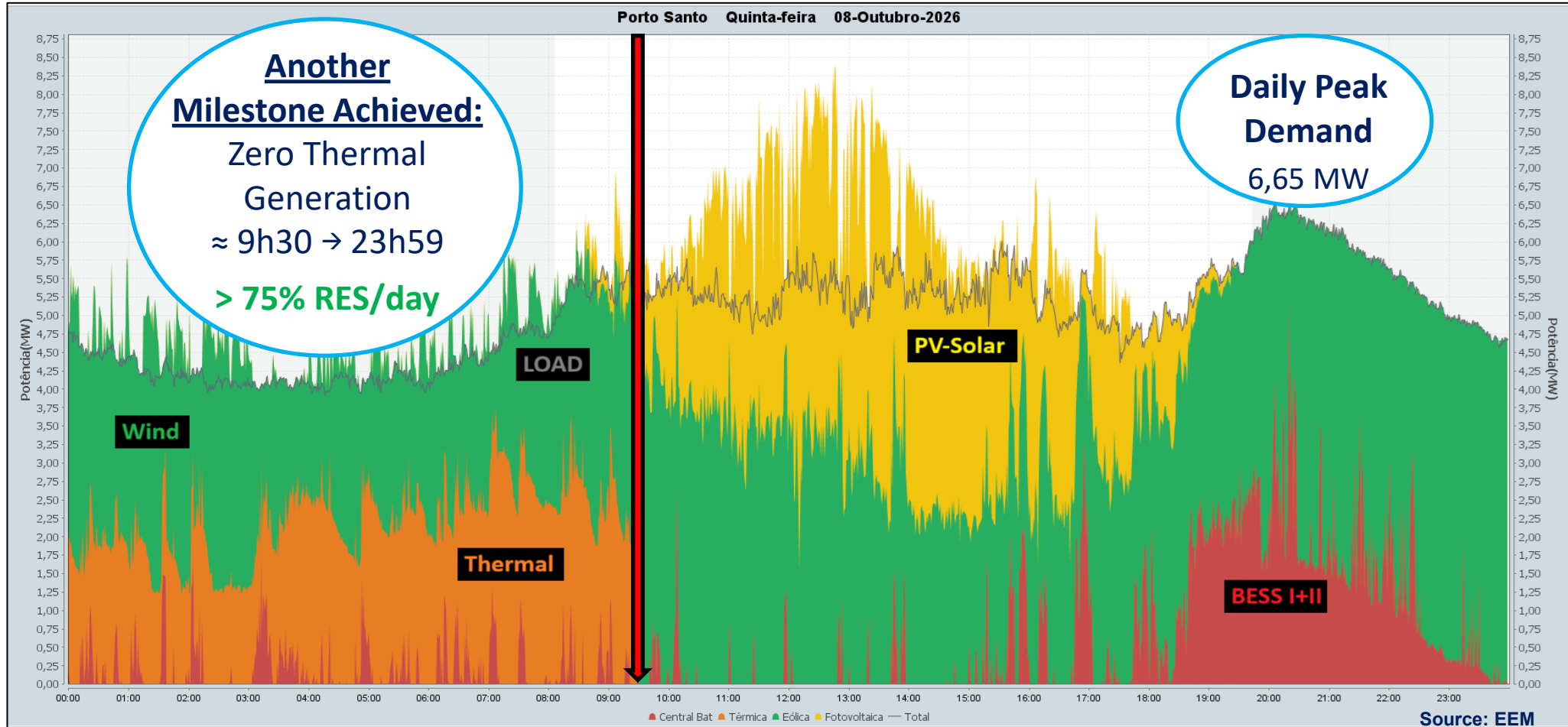
BESS Porto Santo I + II + New PV Solar + New Wind Power



OTHER IMPACT & PRACTICAL OUTCOMES

II Congreso Sistemas Eléctricos Aislados Tenerife 2026

BESS Porto Santo I + II + New PV Solar + New Wind Power



FUTURE AND OPPORTUNITIES:

How to Operate a Power System with High & Low RES Penetration?

PAST

- **Grid instability** (hard to control frequency and voltage), with the risk of electricity blackouts;
- **Very High dependence** on thermal generators to provide ancillary services to the grid, removing space for the renewables integration and thus resulting in some **curtailment** of **RES production**;
- Low energy **storage capacity**;
- **Less robust** power systems;
- Absence of **controllable loads**;
- Major challenges to **Power System Stability and Security of Supply** in isolated, small-scale outermost islands such as Madeira: Intermittent Renewable Generation, Demand Variability and DER Integration;
- **No weather forecast data**;
- **No specific regulatory framework** for non-interconnected islands...

PRESENT

Structuring Madeira's power systems to operate without fossil fuels:

- **HW/SW support:**
 - **TSO → SCADA/AGC** – Use of consolidated management instruments | Smart Grids technologies (**weather forecast models** and dataset, sensing, remote command, communication systems...) | Coordination with global management system (**AGC**);
- Storage assets (**Reversible Hydroelectric Power Plants** and **Battery Energy Storage Systems (BESS)** with grid-forming and black-start capabilities);
- Strategic asset: **Synchronous Condenser**;
- **DSO → ADMS**/Distributed Energy Resource Management System (**DERMS**) → part of an **ADMS architecture**;
- **High level** trained technicians (HR);
- **Regulatory and legal framework** that ensures **new RES** installations to support Madeira's power systems (local **Grid Code** since 2019)...

FUTURE

- ✓ Greater and higher-capacity **storage assets + fast-response systems** (“GWh” water reservoir, very large-scale BESS, synchronous condenser...);
- ✓ More **Demand Side Flexibility + DSM** features;
- ✓ **AMI** – Advanced Metering Infrastructures (smart-meters information → **smartening and digitalization of the grid** + real time customer consumption profiles) → **SMART GRIDS**;
- ✓ **EVMS** – Electrical Vehicle Management System → **V1G/V2G** smart-charging, innovative projects deployment from past European Pilot Projects;
- ✓ Support from more hybrid/decentralized **RES installations** - attractive conditions for private investment in **RES sector** under competitive circumstances + **specific legislation**;
- ✓ Support from Madeira **prosumers and aggregators** – more (renewable) energy communities (**REC**);
- ✓ Alternative, “**more sustainable**” **thermal power plants** (decommissioning of old thermal plants);
- ✓ **A.I. support** for smarter, more efficient, reliable, and sustainable power grids and support of **SW applications**...

LONG-TERM OUTLOOK 2030 → 2050: Autonomous Region of Madeira Power Systems

The 2030 TARGET

- The investments made and supported by **EU** (mainly **POSEUR** and **PRR**), will allow the achievement of the RES targets in the electricity production mix, by **2030** (**55% - Madeira** | **55% - Porto Santo** (≈ 70%))

The new long-term challenges – Regional Energy Policy:

- **2022 ACTION PLAN FOR SUSTAINABLE ENERGY AND CLIMATE OF THE AUTONOMOUS REGION OF MADEIRA (PAESC-RAM)**

- PAESC-RAM targets to **95% RES in the electricity production mix by 2050**

In line with the European strategy for the ENERGY SECTOR:

- ✓ Ensuring a Secure and Sustainable Energy Supply
- ✓ Accelerating Climate Change Mitigation
- ✓ Driving Economic Competitiveness and Employment Growth





- Diogo Vasconcelos (PM-DEP-EEM)

dvasconcelos@eem.pt



Electricidade
da Madeira

Thank You!
Gracias!
Obrigado!

Source: EEM

More information?

<https://eeminov.eem.pt/cb/>

<https://www.youtube.com/watch?v=9tub8osqnY0>

<https://www.youtube.com/watch?v=IXyCgWDZj6s>

<https://www.youtube.com/watch?v=S9tpRr5iX5Q>

<https://www.youtube.com/watch?v=D2fZgd8e3PM>