# Réseaux sous tension
# Grids under stress

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# Why this topic at ASPO?

**Peak demand instead of (geologic) peak oil and gas?**

- Transition to substitute for fossil energy
- But how? With which form of energy?

**The realistic candidate: electricity**

- Electric vehicle instead of thermal vehicle
- Heat pump instead of gas fired heater
- All electric processes in industry (or with H2 produced by electrolyzers)
- Efficient and convenient for customers
- Already large systems to provide it

**! Electricity has some limitations**

# Electricity must be produced and is not storable

Production from a primary form of energy (waterfalls and steam engines in first grids).

Adjustment at each instant to balance the demand
i.e. over 1/10 s, s, min, hour, day, week, year

Indicators to control the equilibrium
- Voltage frequency at grid scale: 50,0 (or 60,0 USA) +/-0,1 cycles/s
- Voltage magnitude locally: from 400 kV - transport lines - to 380 V - distribution - +/-5% (current/voltage phase shift or reactive power)

Power reserves at different time scales (using frequency)
- Instantaneous or grid “inertia”
- At few seconds (turbine regulator)
- At several min.
- At hour
- …

# Wide area electric grids

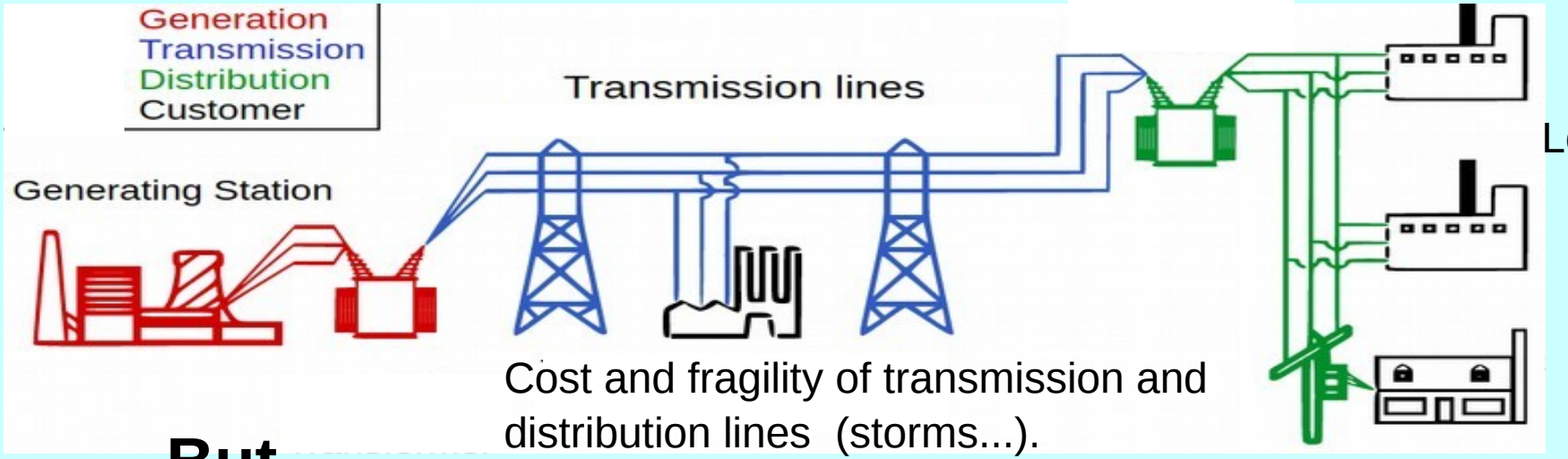
Synchronized at country or even continent scale (Europe/ENTSO)

Economy of scale (large generators..)

Large turbine inertia

Smoothing of demand spikes

Services in common (frequency and voltage reserves...)

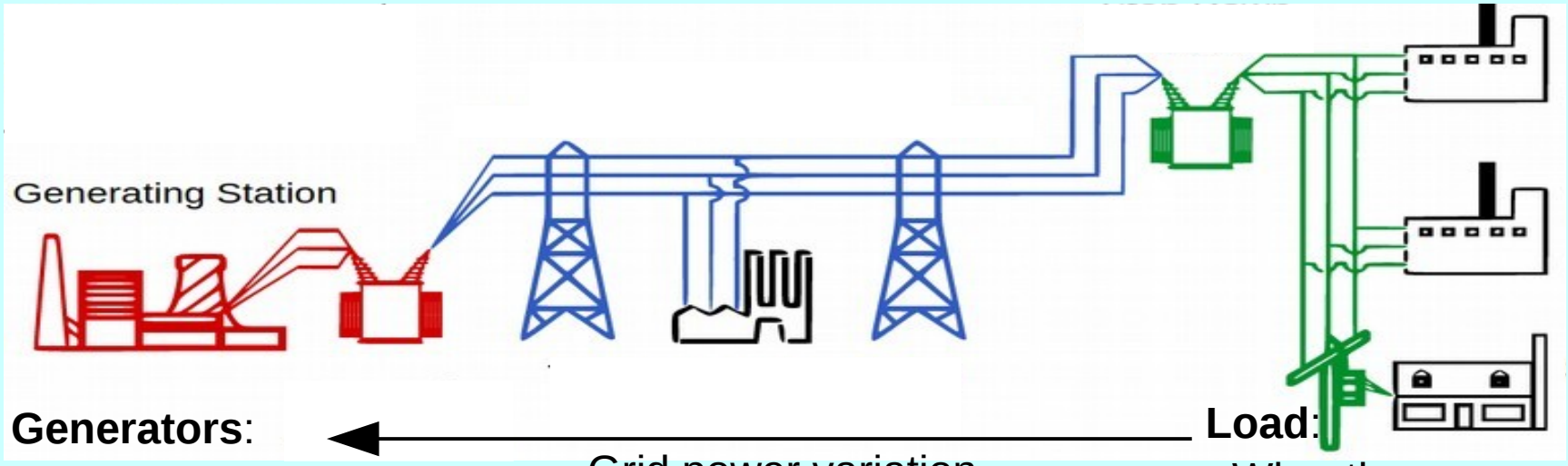



**But**

Cost and fragility of transmission and distribution lines (storms...).
Risk usually localized

**Risk possible of unbalance at grid scale, i.e. blackout**

# Grid balance




**Generators**:
- modulation
- dispatchable in stand by

Grid power variation

**Load**:
- Wheather
- Activity
- Price (~ Cost of the system)

**<u>Grid scaling event under study (day - year)</u>: record consumption while generators under stress.**

**Need of sufficient <u>reliable generators</u>: ready to provide their maximum power when necessary and for long > 48 h (not only dispatchable).**

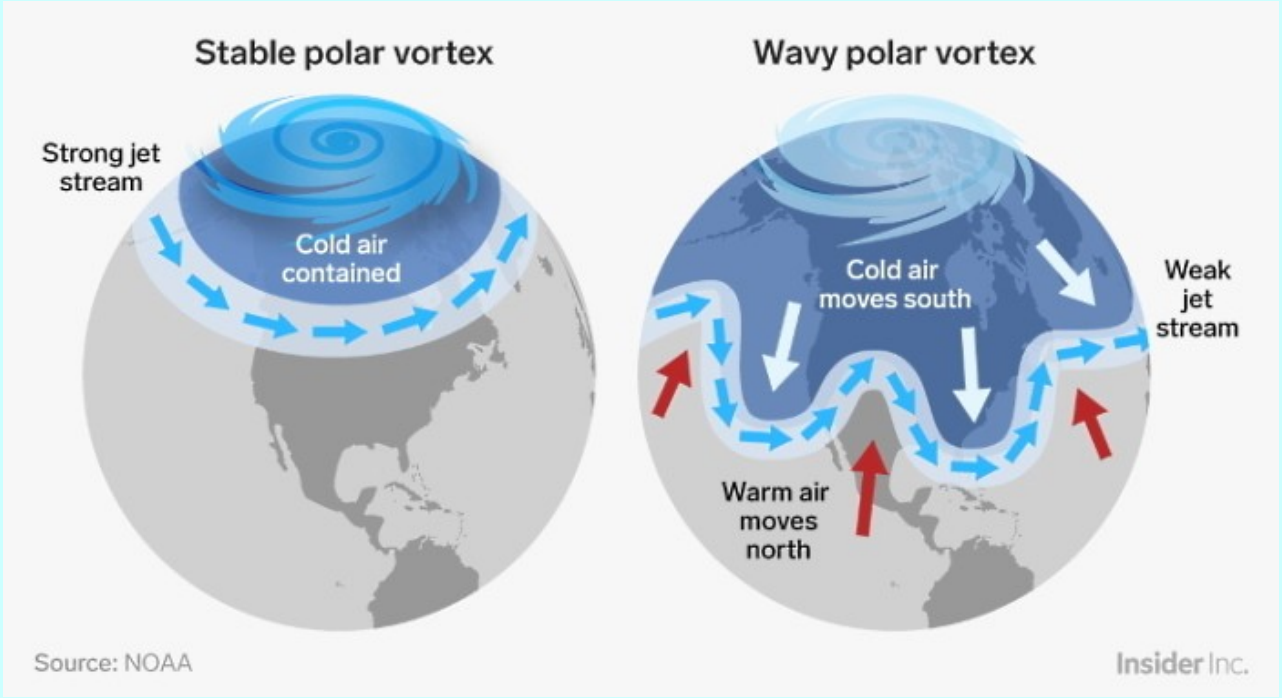
**<u>Cost of the system</u> = satisfy demand every time (> 8760 hours a year).**

**Not too low but not too much: efficient generation planing.**

# Texas February 2021

Ref: Chavanne, X. (2024). Hiver 2021: délestage massif sur le réseau électrique texan–Leçons pour la France. Revue de l'Energie, 672(3), 55-66.

# Polar incursion




<u>First weeks of February 2021</u>

Very cold air from Arctic down to south of US.

Unstable phenomena make for difficult forecast.

Texas was hit hard from 14th to 19th of February.

**Its grid – managed by ERCOT - was overwhelmed**

# What happened?

| GW | | | | | | | Total/load |
|---|---|---|---|---|---|---|---|
| Capacity 2020 GWc | 78 | 30 | 19 | 5,1 | ~5 | | 139 |
| 2021 avg production | 27 | 11 | 10 | 4,6 | 1,7 | = | 55 |
| Expected during winter highest peak | 56 | 7,5 | 13,5 | 5,1 | 0,3 avg | > | 67 |
| What happened | ~30 | 0 - 5 | ~8 | 3,8 - 5,1 | 0,3 avg | < | 75 |

Unplanned outages, lack of fuel, unable to start

PV was as expected

1 reactor tripped for 2 days due to a sensor in turbine circuit

**Reliable generators (thermal plants) failed for lack of preparedness and resilience.**

# Why reliable generators failed?

Analysis of American Society of Civil Enginers (founded in 1852, 150 000 members):

- Lack of revenue even operating at loss.
- A liberalized market unable to remunerate reliable generators.
- Unfair competition from unreliable plants.
- no incentive for reliability

**Texas senate and house voted two bills to correct that:**

**- grants and low-interet loans to build reliable generators**

**- renumeration mecanism for reliability, penalizing unreliable generators**

**Starting in January 2026.**

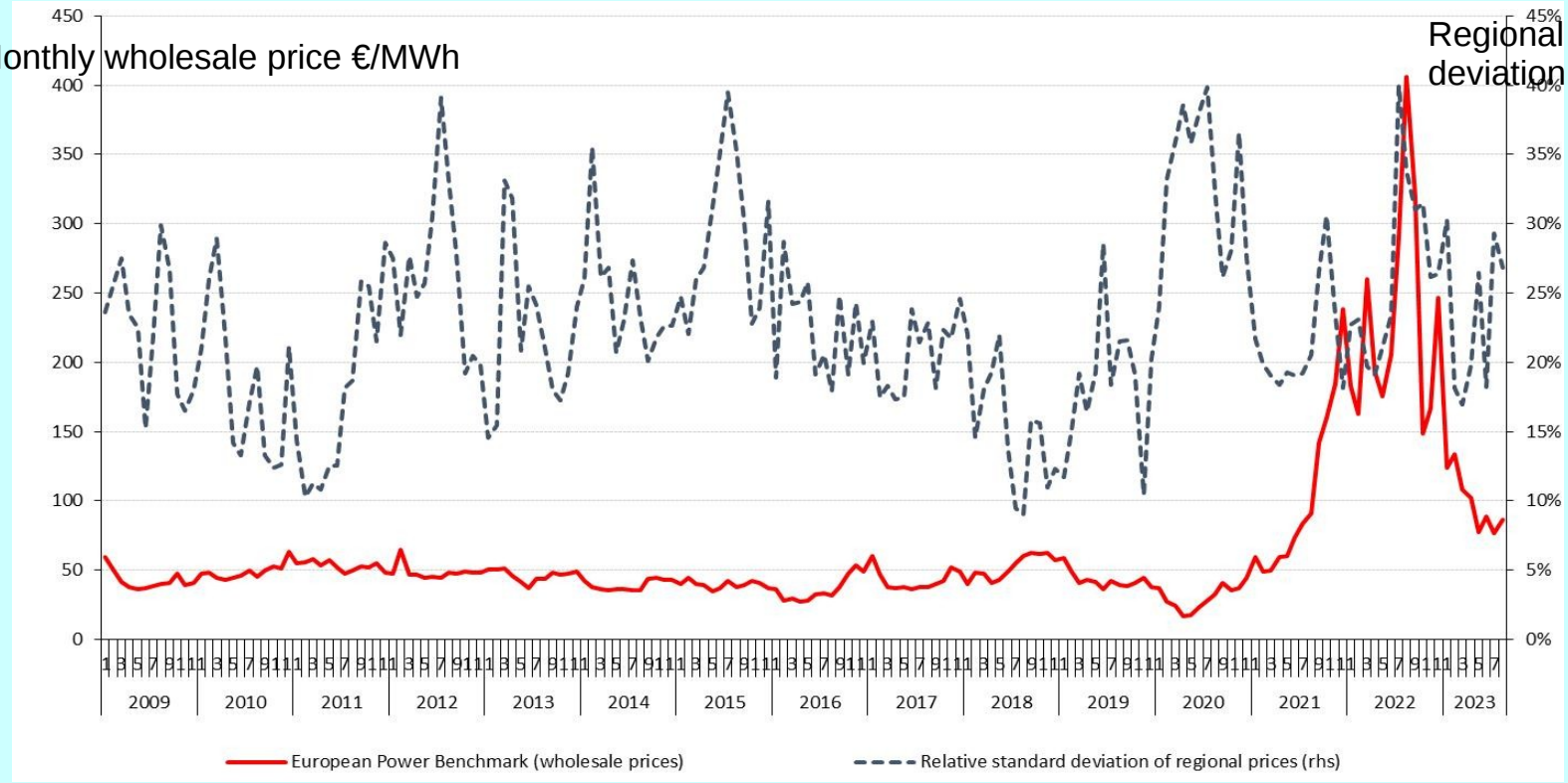
**Help to thermal plants, mainly gas-fired ones.**

**Photovoltaic farms can benefit when coupled with large battery storage**

# European electricty system 2009-25

Ref: Chavanne, X. (2025). Le réseau électrique français peut-il subir la crise de celui du Texas lors de l’hiver 2021?. La Revue de l'Énergie, 677(2), 35-56.

# Electricity in Europe 2009-24

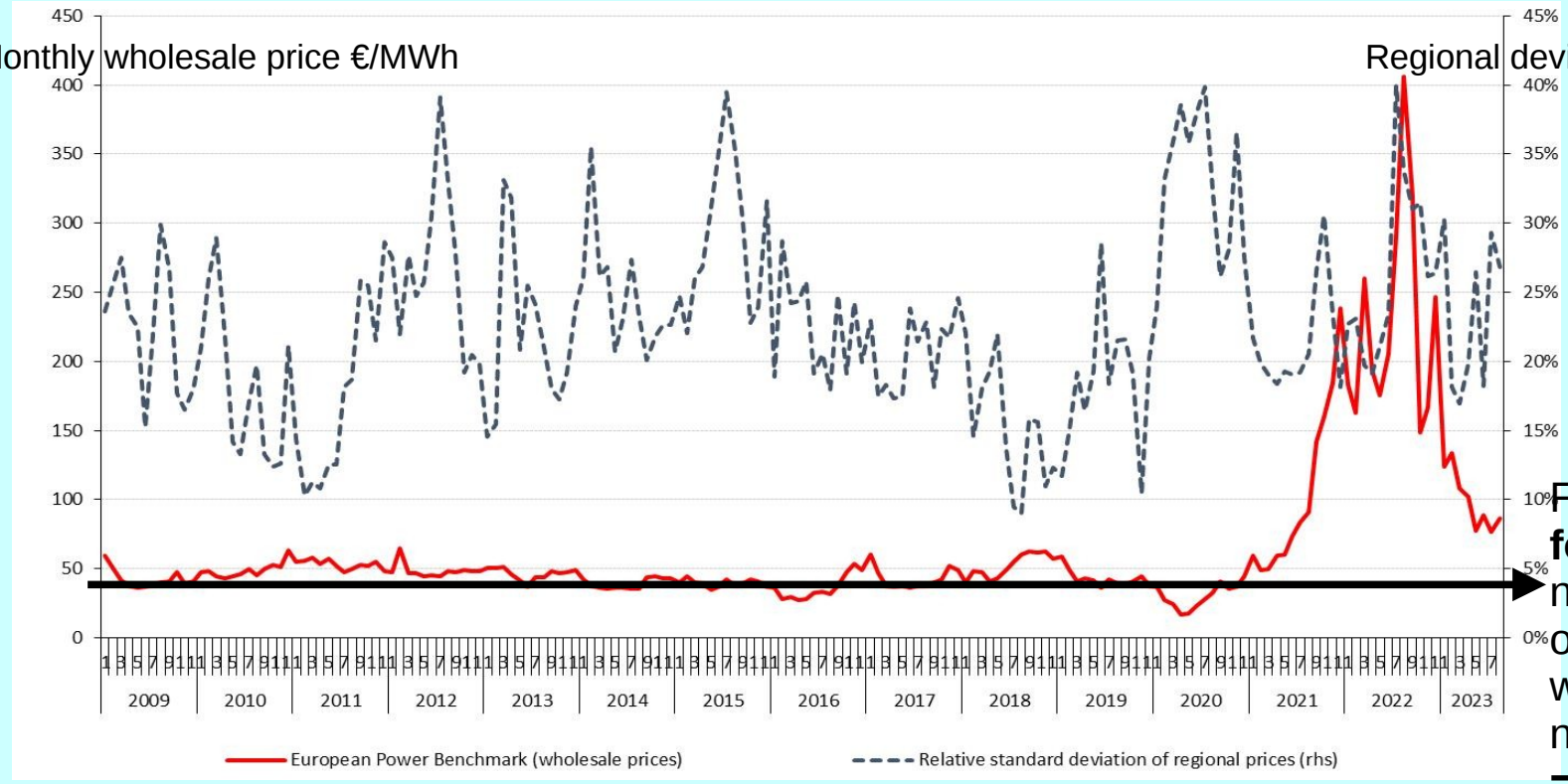



Germany: very low whole sale price for very long + policy to close nuclear plants and then coal fired ones + heavy subsidies to wind turbines and PV.
Closure of 42 GWc (coal, nuc) against new 20 GWc (gas, biomass)

Wind capacity from 25 to 72 GWc, PV from 25 to 99 GWc

Big utilities, E.ON, RWE and Vantefall close to bankruptcy

# Electricity in Europe 2010-24




Forced price of **42 €/MWh for 100 + 100 TWh/year** of nuclear output = costs to operate existing plants without life extension and new units
**= effective phaseout**

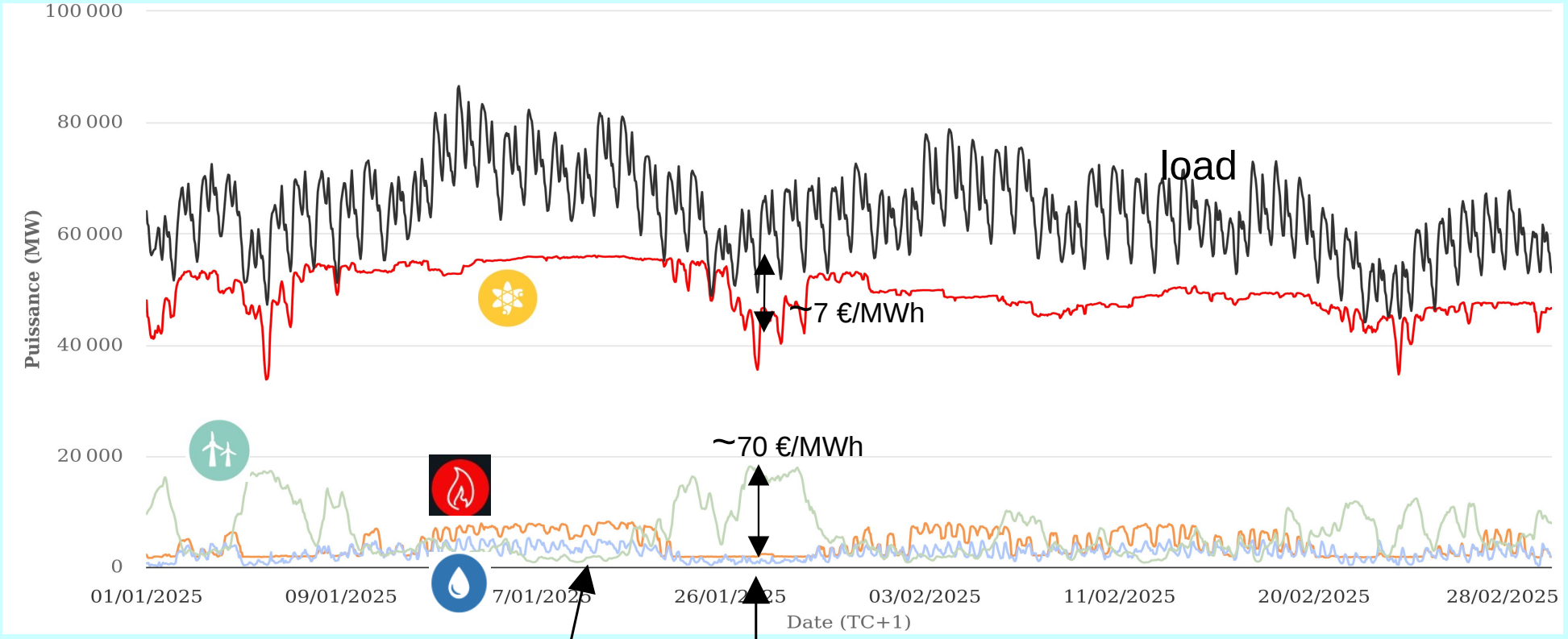
France: very low wholesale and forced prices for very long + policy to close coal and oil fired plants and some nuclear ones. Heavy subsidies to wind turbines and PV.

Closure of 17 GWc (coal, oil, nuc) against new 4 GWc (gas, bio)

Wind capacity from 5 to 26 GWc, PV from 2,5 to 21 GWc

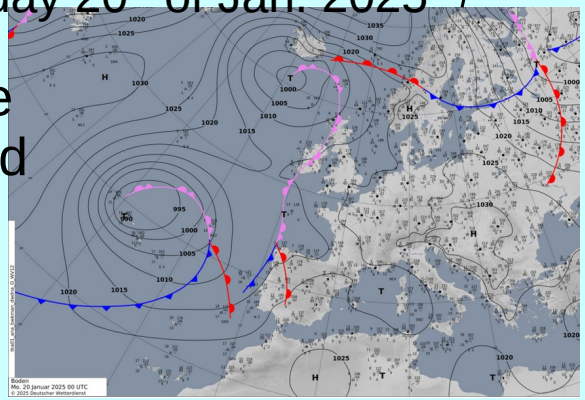
EDF unable to finance life extension of its plants and new units except by debts

# French grid winter 2025




Monday 20th of Jan. 2025

Anticyclone
Cold air and
low wind



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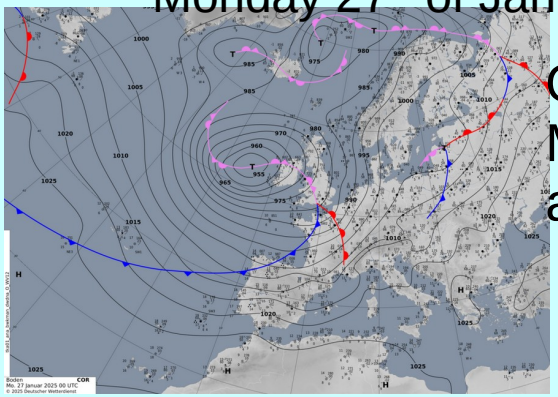
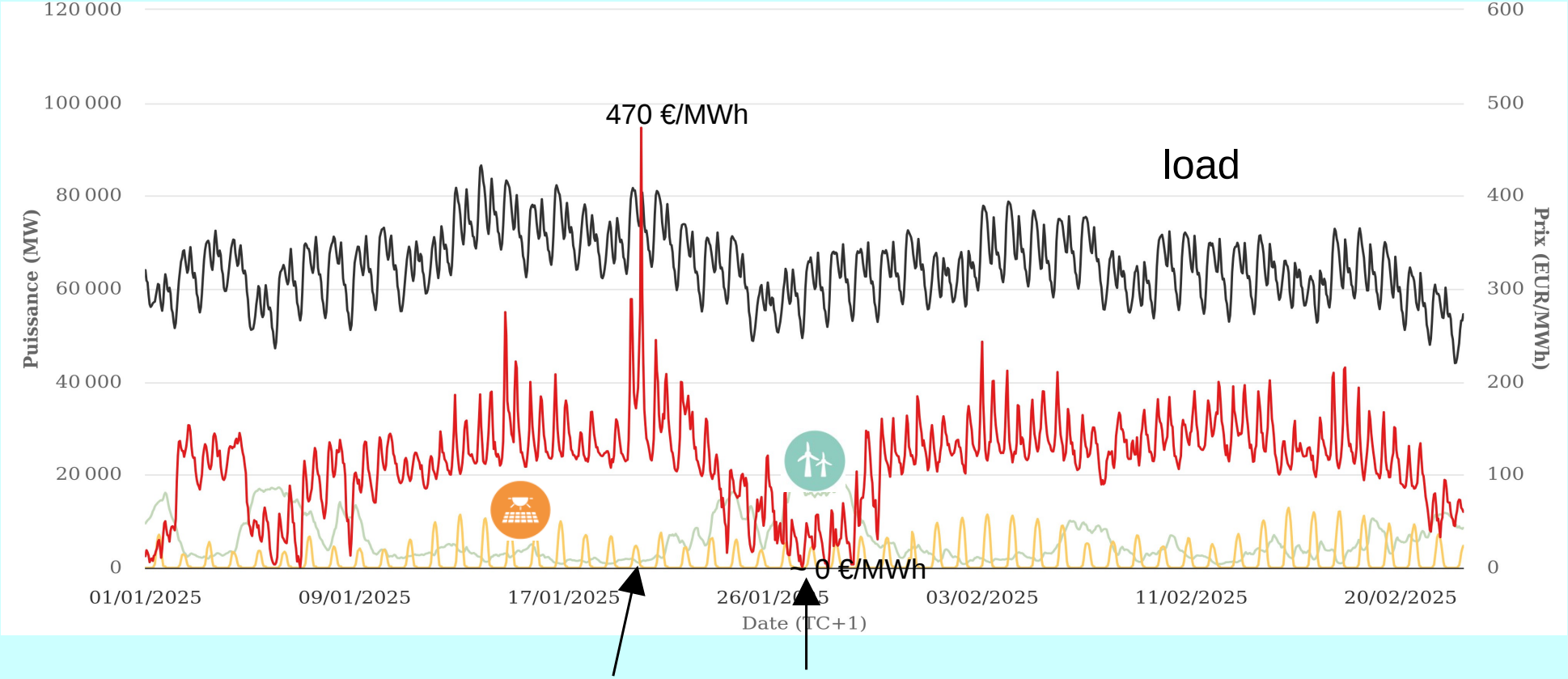


Oceanic depression
Mild temperature
and windy

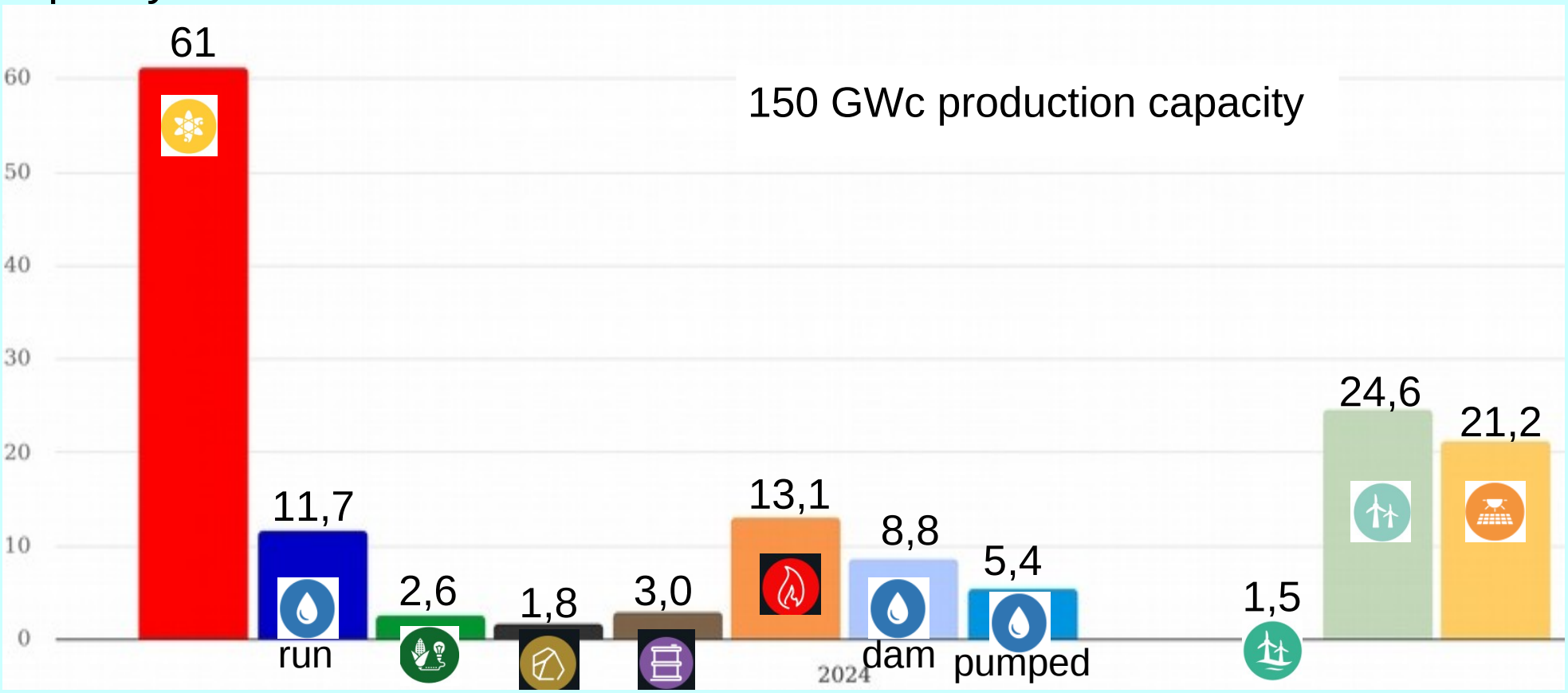
# French grid 2025: spot price




Wholesale price helpless to guide long term investment
But at least a short term indicator of stress on the grid :
- low or negative prices, too much electricity produced
- high prices, electricity production is need.

# Required generation

Capacity GWc. France end 2024. RTE




**Is capacity an indication of reliable power for record consumption during rare event ?**

**It contributes to part of the cost of the system (capital).**

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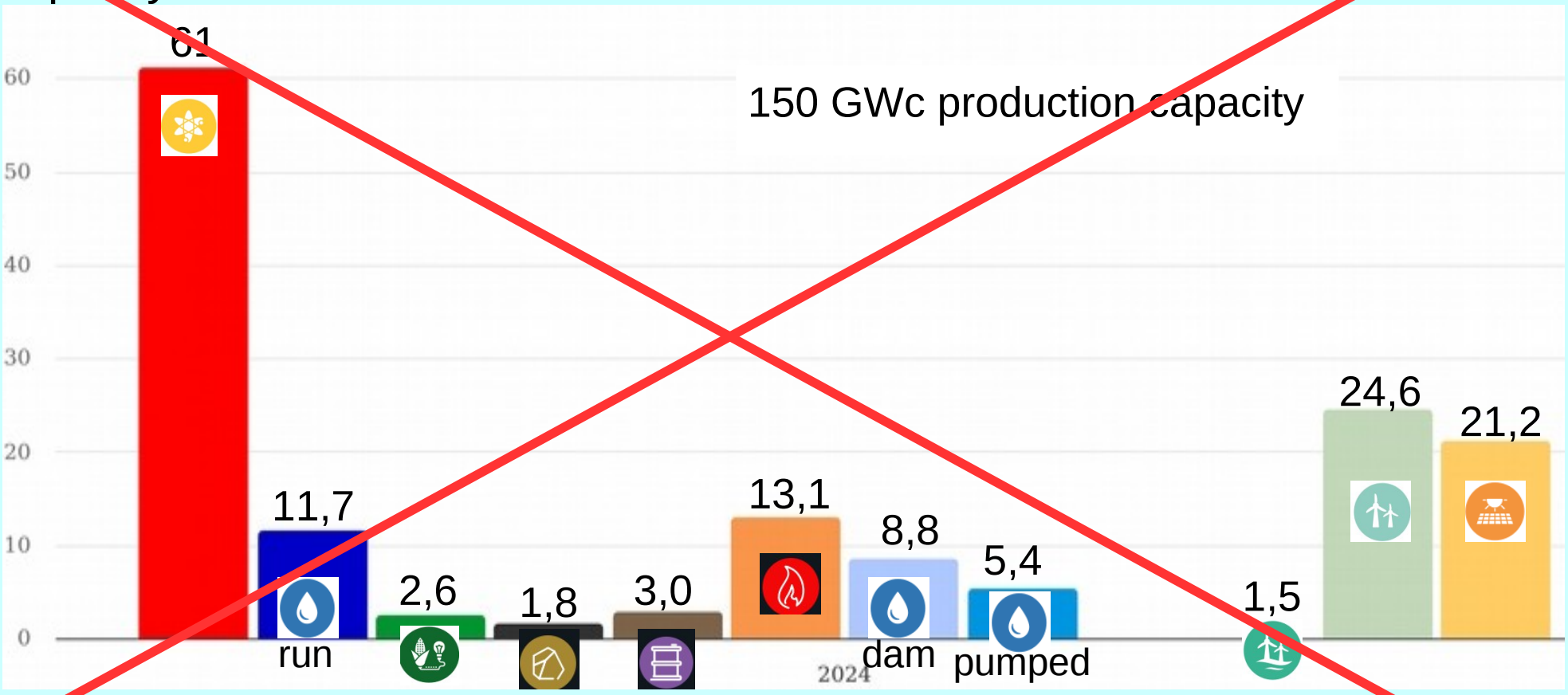


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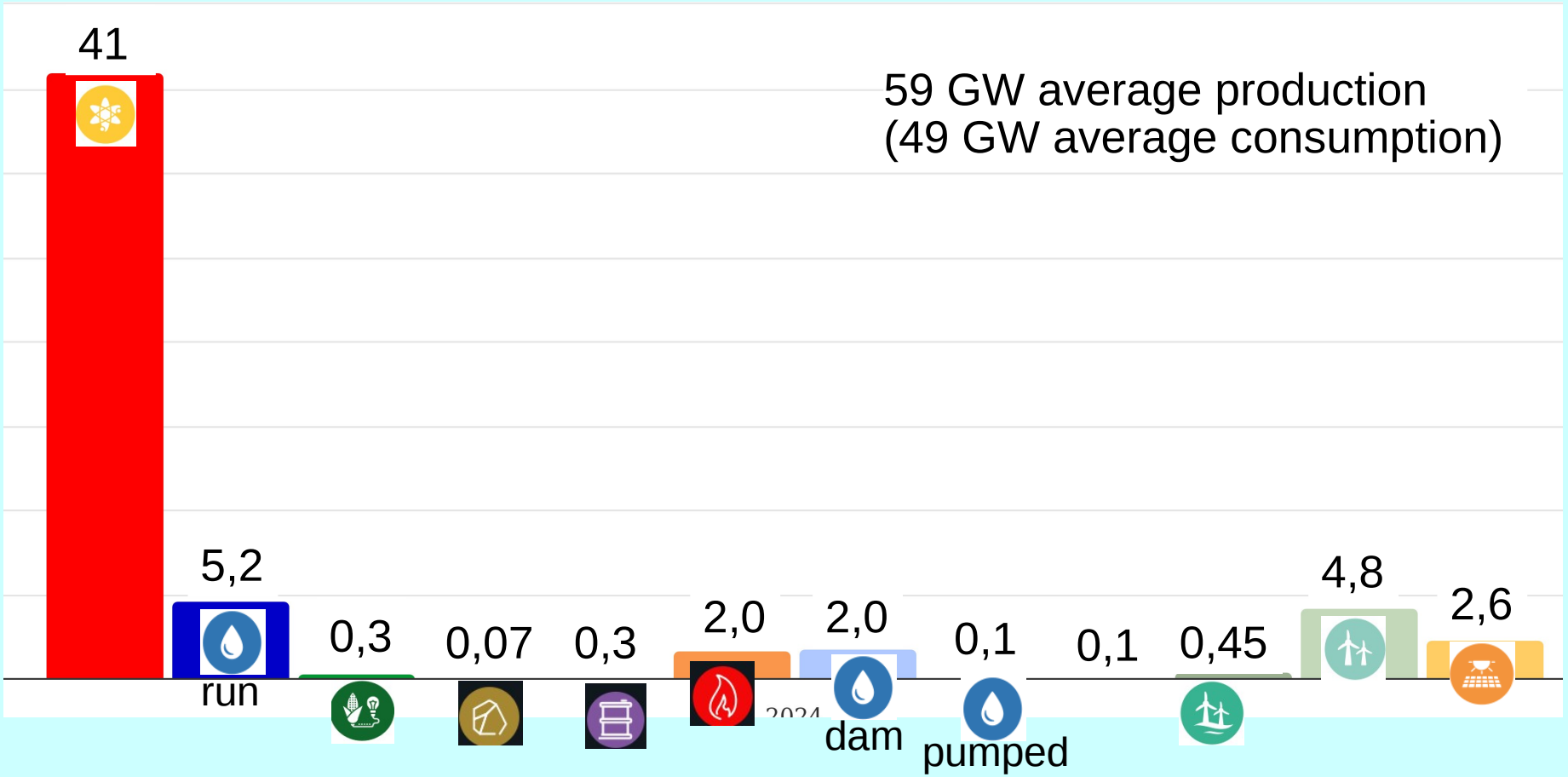


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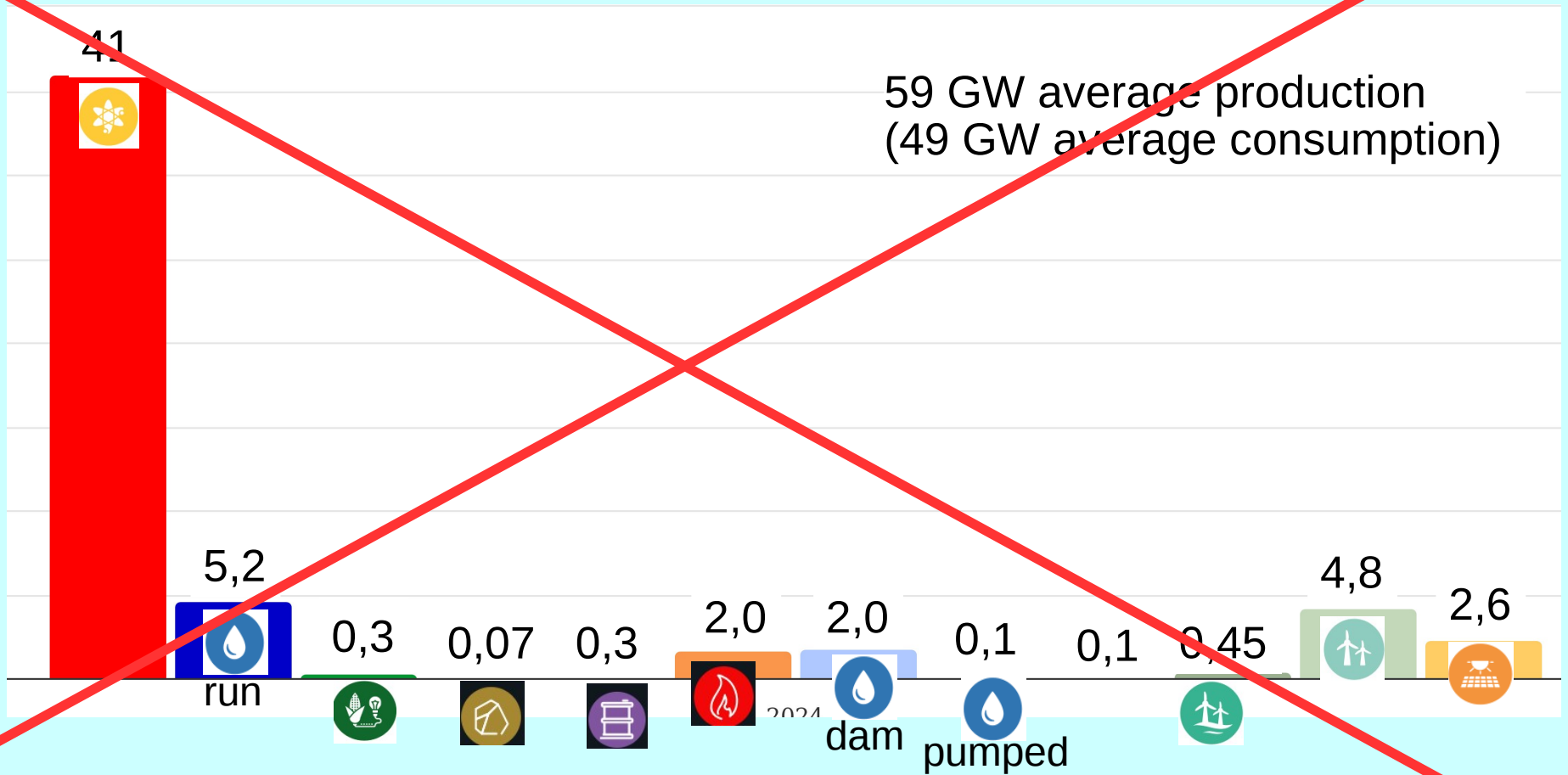


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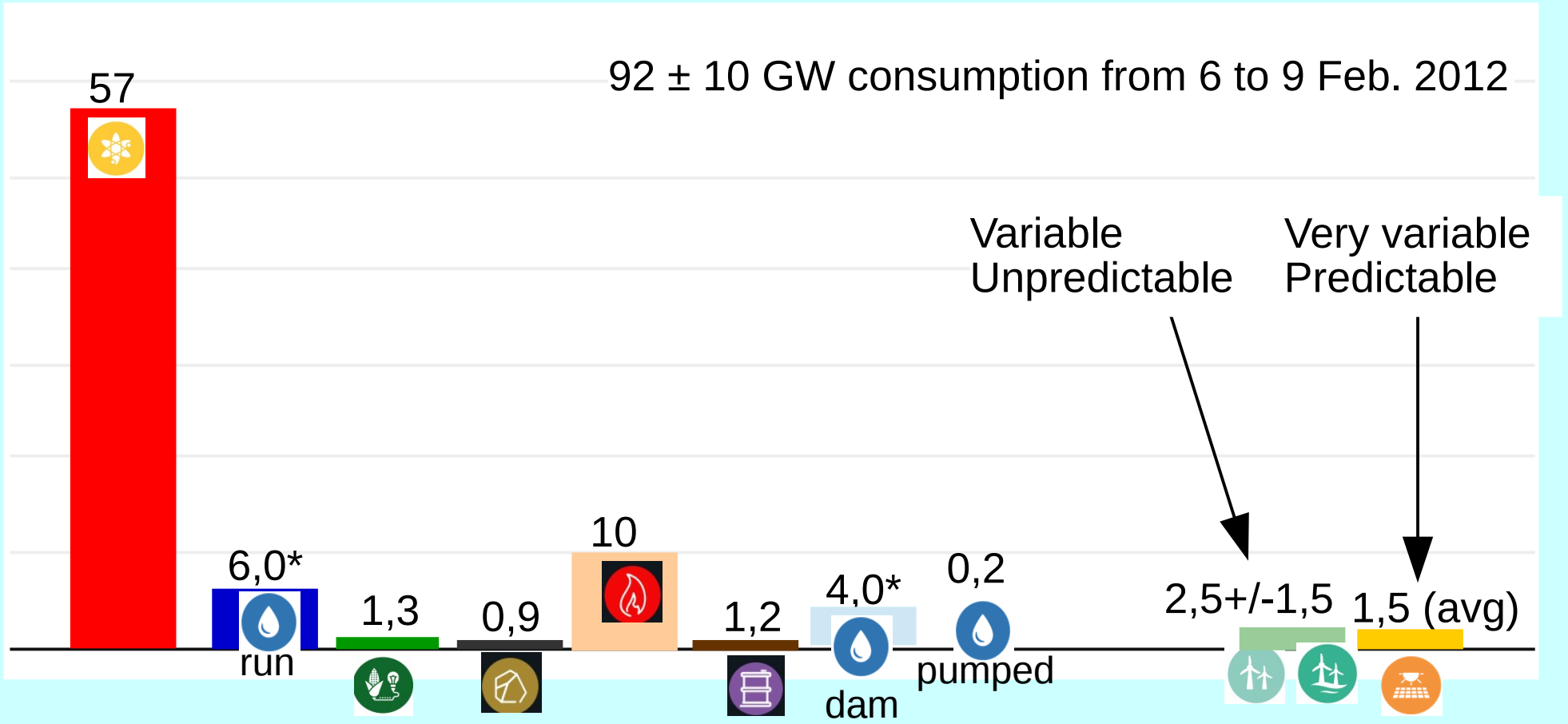
Capacity 2024 x avg load factor from 6 to 9 Feb 2012 GW. France



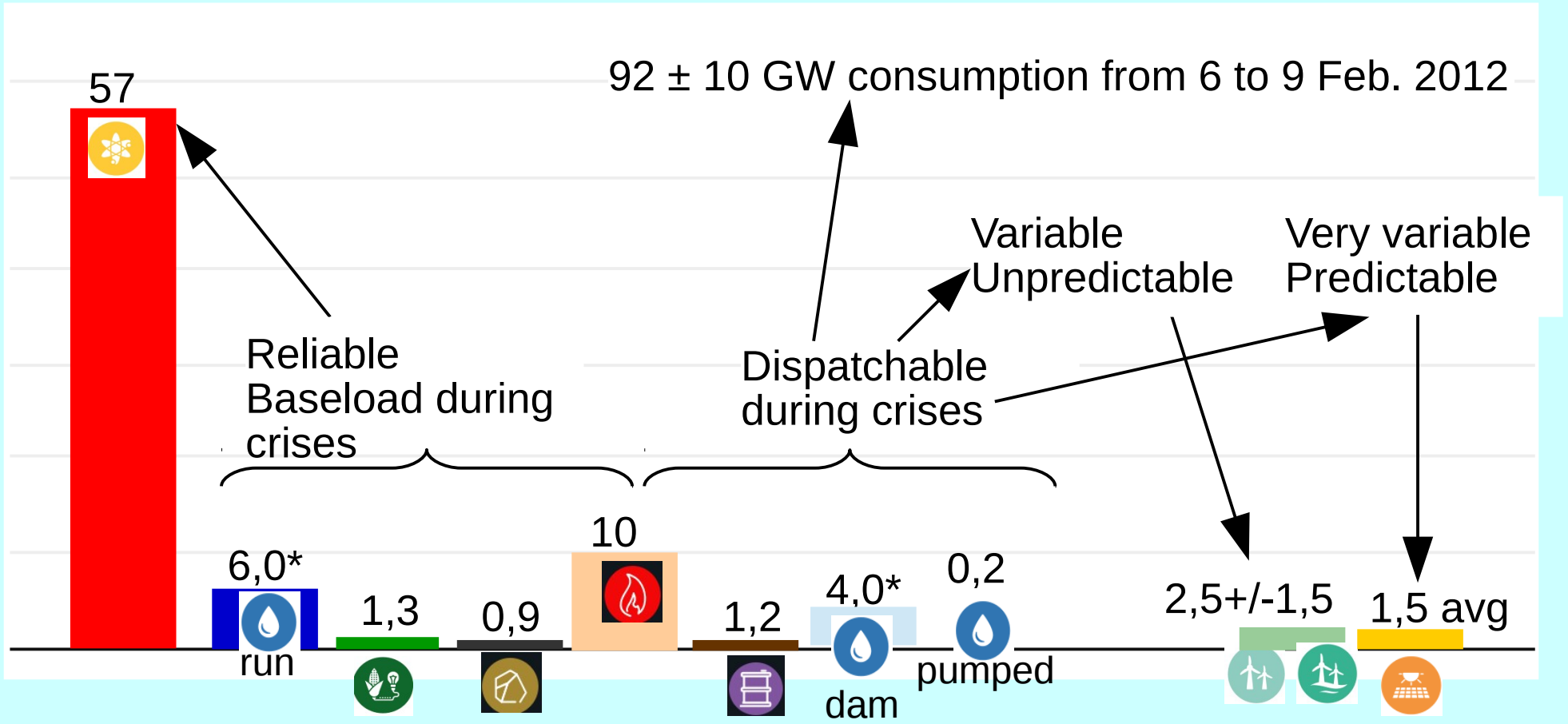

**Model of contributions to production in case of a peak load as in Feb. 2012**

NB: production of 85 GW in average with 2024 capacity

*: levels depend on amount of precipitation over previous months

# Required generation

Capacity 2024 x avg load factor from 6 to 9 Feb 2012 GW. France



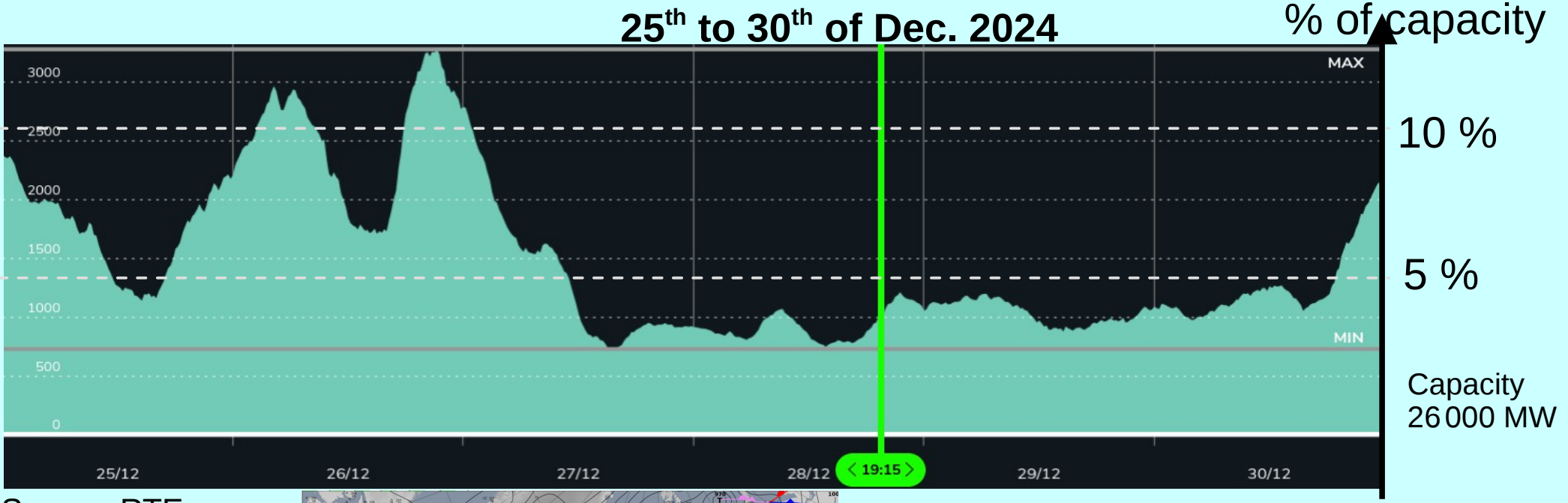

**Thermal and hydro plants are the reliable generators during crises.**

**Pumped hydro and from dams convenient to adjust variable wind and PV plants.**

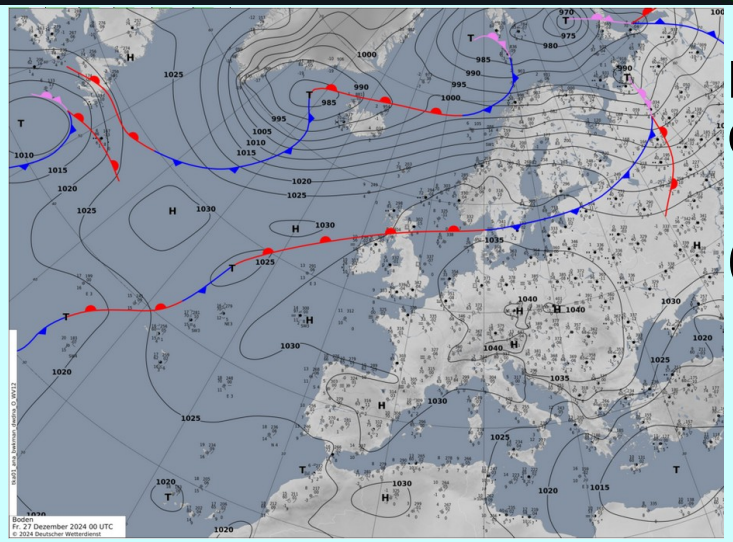
**The only ones. Wind turbines output as low as 5% of capacity for days.**

# Wind plant generation

**25th to 30th of Dec. 2024**



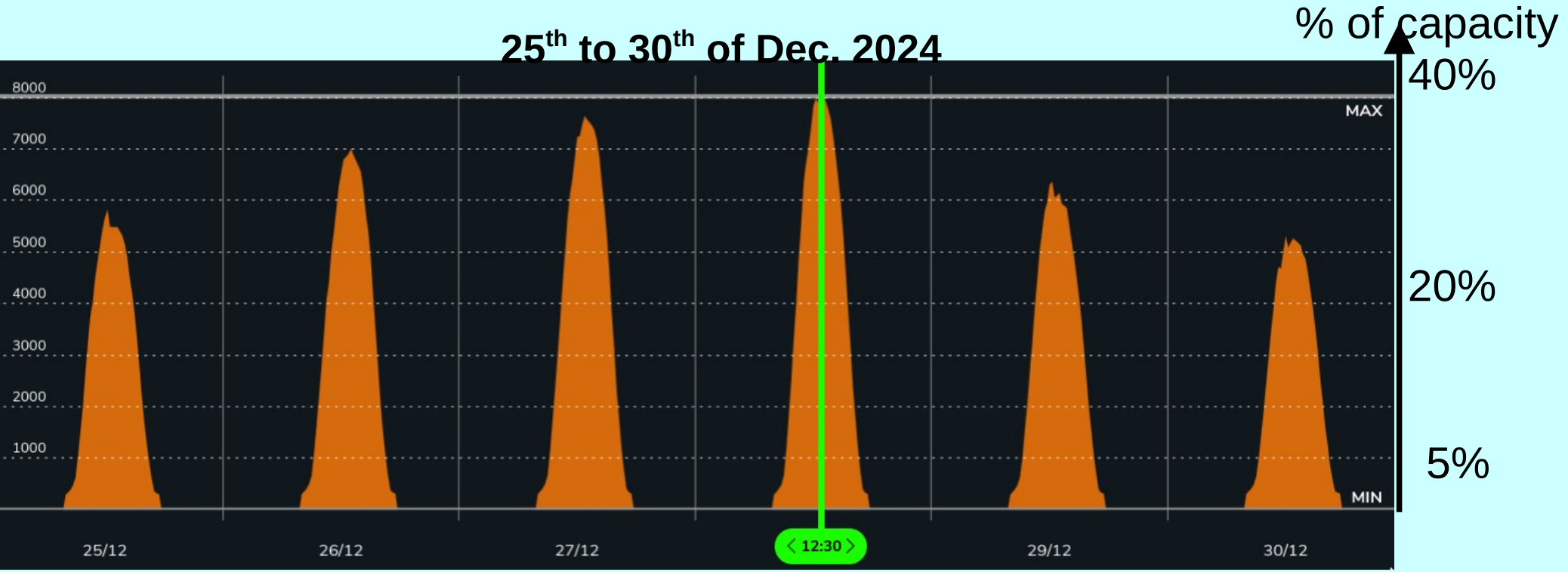

Source: RTE



Large anticyclone over western Europe :
Cold air and low wind

(fortunately during a holiday)

# PV generation




Source: RTE

Production capacity
21 200 MW

PV mainly in french southern with more sun

Winter solstice, the shortest daylights of year. Production peaks at less than 40%. Five and half hours above half of the peak each day. In winter can be managed with pumped hydro.

NB: from March to October the solar peaks become too big to be managed by hydro alone. Spot prices dive around the peak time. Europe wide problem.

# Very cold snap over days and at grid scale

- Record consumptions => record production

- Generators able to cope with → reliable generators

- They are mainly thermal and hydroelectric ones

- Since 2000s the ones which have most suffered from energy policy and liberalized markets in Europe and Texas

-Risk of systemic failure at Europe scale as lack of generation occurs at the same time everywhere

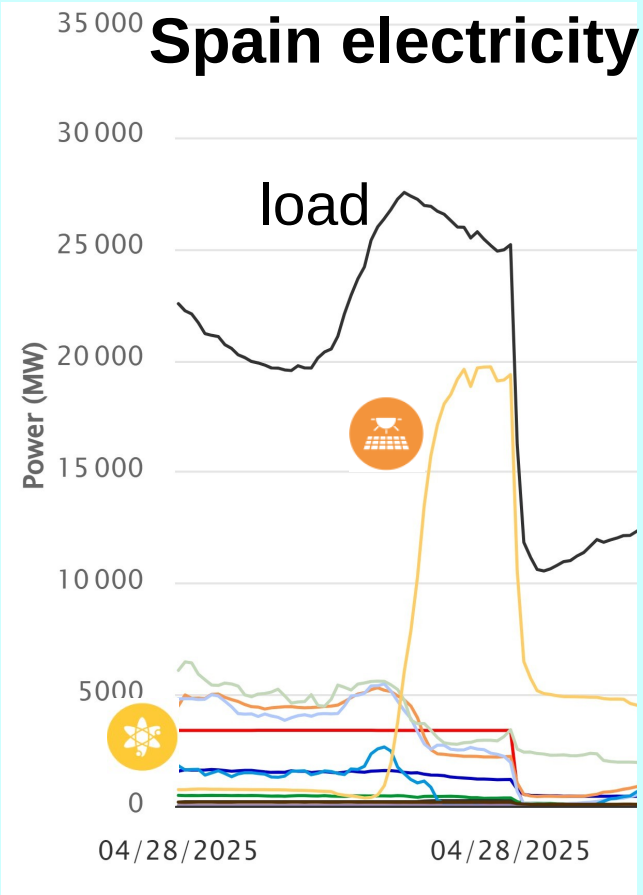
# Challenge for grid scale

- Sufficient reliable generators for record consumptions
- Generators underutilized in normal conditions, but to be maintained
- Cost of the system too high
- Ideally grid with only reliable generators, with part of them shutdown except in winter (French electrical system before 2000s).

So what about PV and wind turbines?

In Europe usefull when saving fuels for reliable generators like gas and water in storage

# What happened in Iberia peninsula the 28th of April?

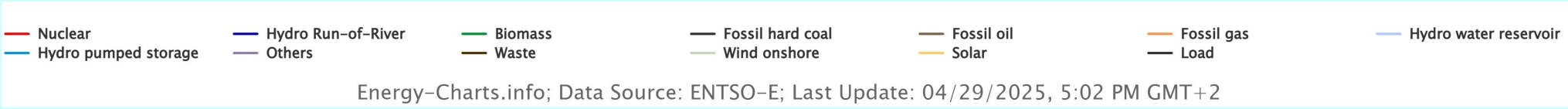



**Grid balance at scale of 1 s with overproduction**

From 12:33:16 (CET) and within few seconds a succession of generators disconnected from the grid, destabilizing even more the system until disconnection from the rest of Europe and the blackout over Iberia peninsula.

Just before Spain production was 29 GW, of which 4 GW exported to Portugal, France, and Morocco:
- 18 GW from photovoltaic
- 3.5 GW from wind power

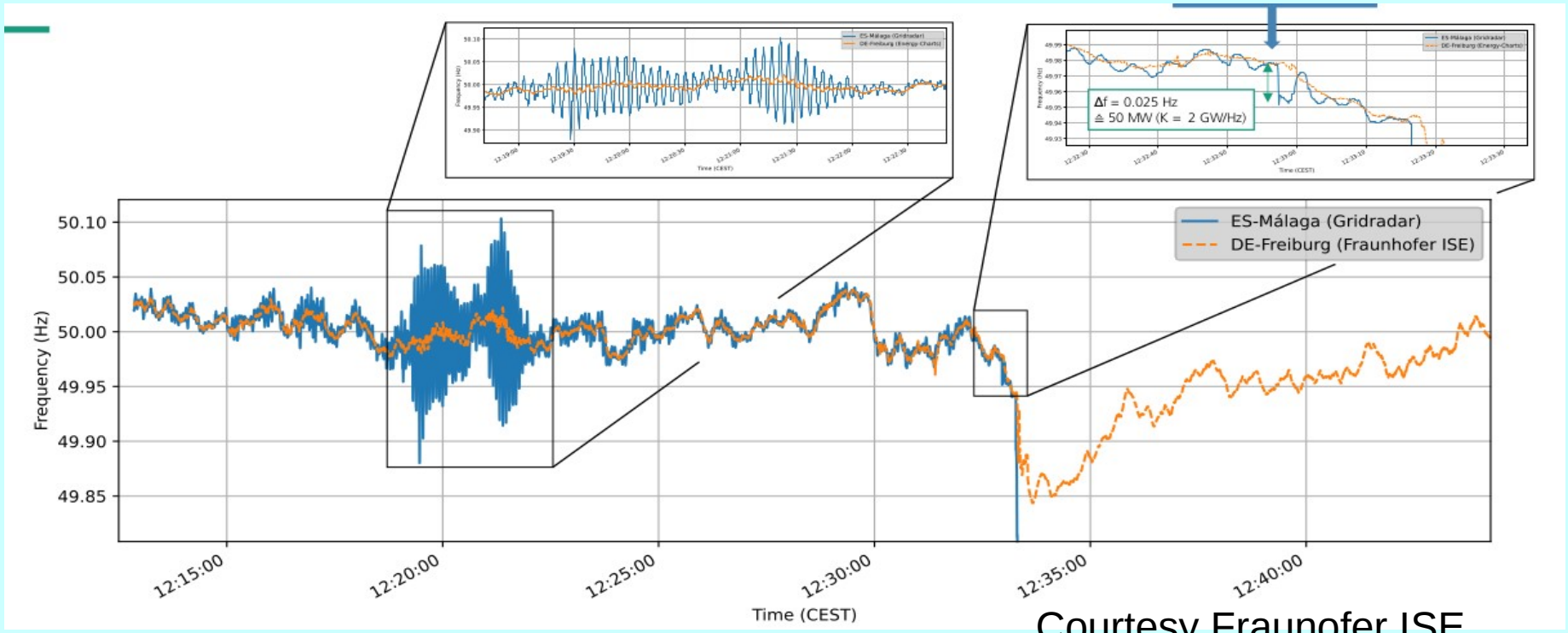
Synchronous generation came from nuclear (3.5 GW), fossil (2 GW), biomass (1 GW), and solar thermal (1 GW)



# What happened in Iberia peninsula the 28th of April?

Spanish grid suffered from a lack of inertia which makes it very sensitive to any disturbance → large oscillations of frequency and voltage -> loss of generators (Southeast of Spain; PV probably) -> amplification until the blackout

-25 mHz -> 50 MW loss




Courtesy Fraunofer ISE

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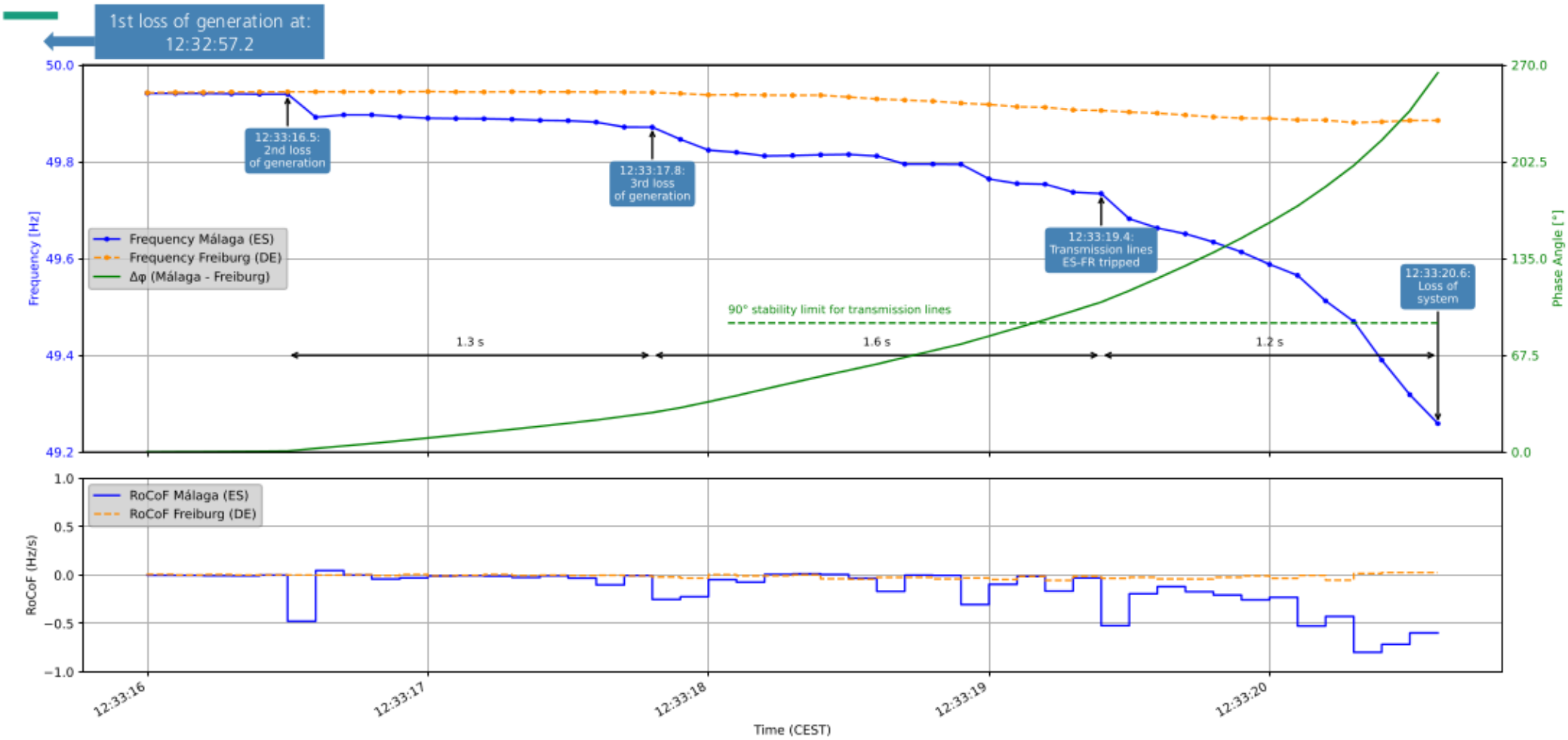


Courtesy Fraunofer ISE

# Tentative conclusions

- Balance of an electric grid at scale < s with over production.

- Resulting from too much photovoltaic electricity nearly at same time in all Spain (In addition of negative wholesale prices not supported by owners)

- Stability could be maintained with high PV production but it requires better power electronics and algorithms with large battery storage (numeric reserves). It may be also more complex for a large grid.

- Tariffs do not favor a reliable and flexible generation while costs are rising (dixit the president of Bundesnetzagentur)

- And it would not solve the threat of very cold snap

**Thank you for your attention.**

**Any question?**

# France 2024

Yearly production/consumption GW