CentraleSupélec

cnrs

Inria

UGA Université Grenoble Alpes

UVSQ

université PARIS-SACLAY

TASE Days

climatEXload

June 29, 2026

PowDev · Heatwaves & grid resilience

with Anne Barros · Théotime Coudray · Ibtissem Khelifati
Anastasia Akakpo-Numado · Grace Domaya Nekouanodji
Alicia Bassière

POWDEV

RÉPUBLIQUE FRANÇAISE
Liberté Égalité Fraternité

anr agence nationale de la recherche

FRANCE 2030

FRANCE · JUNE 2026 · HAPPENING NOW

Not a scenario: this was last week

43.8°C
peak at Saintes (24 June) · 40°C+ across much of France

72
of 96 mainland departments in red alert (25 June 2026)

+10 GW
extra demand from the heat, 22 June ≈ 10 reactors

- Ran 17–28 June; 24 June was the hottest day ever recorded in France (29.9°C national average)
- At Monday's evening peak, gas generation jumped from 1% to 7% of the mix to cover cooling demand
- AC sales up +61%, fan sales up +1,500% in one week (Le Monde, NielsenIQ): more equipment means more load during future waves
- RTE projects air-conditioning demand will climb from 6 to 14 TWh by 2050

Sources: Météo-France / Le Monde · RTE · Bon Pote (Goldberg, Terra Nova): Junexa 2026

So how much electricity do heatwaves add: and why? That is what climatEXload measures.

THE PROGRAMME AT A GLANCE

climatEXload: four research axes

1 Heatwave detection

- ERA5 reanalysis + RHITA algorithm
- Regional binary indicator, day by day
- 26 episodes (PACA), 14 (IDF), 15 (Bretagne)

2 Electricity overconsumption

★ WORKING PAPER

- +350 MW (PACA) and +358 MW (IDF) per heatwave hour
- ≈ 0 in Bretagne: explained by AC penetration
- 338 M€ cumulative cost, 2013-2023

3 Grid stress & infrastructure

- AC demand peaks when supply is weakest
- Nuclear derating, wind drought, lower line ratings
- Simultaneous constraints on both sides

4 Socioeconomic disparities

- Who is exposed? Who can adapt?
- Renters, low-income, dense urban areas most at risk
- Double jeopardy: physical risk + financial burden

Heatwaves are becoming a norm

What is a heatwave?

- Several consecutive days of sustained extreme heat
- Defined locally: a hot day in Brest differs from one in Marseille

More frequent, longer, more intense

- The trend accelerates sharply after 2018 in all three regions
- 2022-2026: record duration and intensity across France
- Even oceanic Bretagne now records real episodes

Regional disparities arised from Data analysis



Fig. 2: Annual heatwave activity by region (duration + intensity)

THE TERRAIN

Three regions, three very different contexts

PACA

Mediterranean

47%

AC penetration

Mean summer load	**8,400 MW**
Mean summer temp	**23.7°C**
P90 temperature	**28.8°C**

ÎLE-DE-FRANCE

Continental · largest

17%

AC penetration

Mean summer load	**12,400 MW**
Mean summer temp	**19.5°C**
P90 temperature	**26.4°C**

BRETAGNE

Oceanic

11%

AC penetration

Mean summer load	**4,000 MW**
Mean summer temp	**17.5°C**
P90 temperature	**22.0°C**

Two effects, two mechanisms

1 Thermal effect



- Temperature rises
- Existing ACs run harder and longer
- Continuous and proportional to heat
- Always active during hot weather

Every degree above 20°C adds tens of MW

2 Alert effect (Heatwave specific)



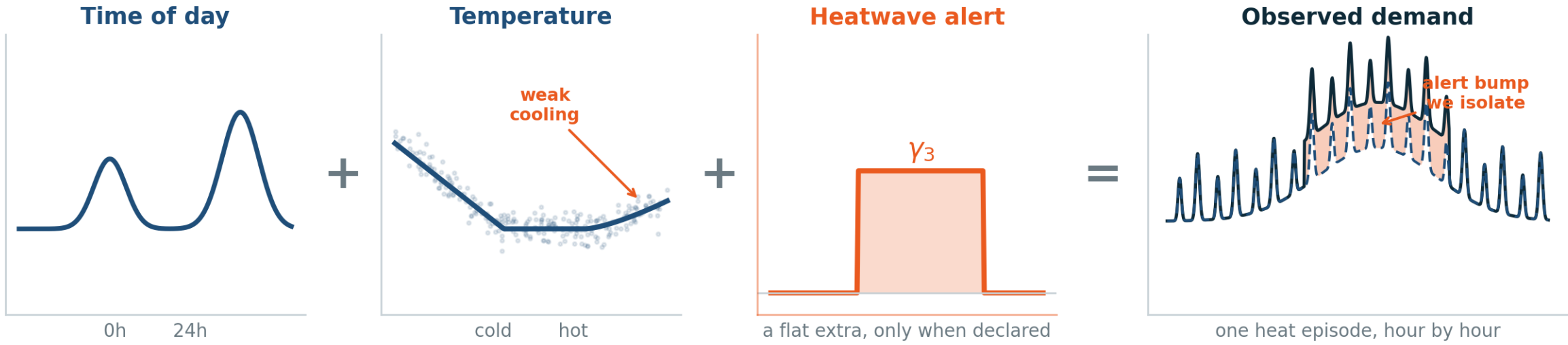
- Météo-France declares a heatwave
- Nights become hot too
- People switch on ACs they would have left off or run toward mobile AC that consume more
- Hospitals & care homes activate protocols
- Public AC

Triggered by the heatwave specifically

THE METHOD, IN PLAIN TERMS

Demand = a sum of simple curves

Each cause gets its own flexible curve, a "spline" fitted from the data. Add them up, and you rebuild demand hour by hour.



The paper's contribution temperature has its own curve, so the heatwave's extra jump stands apart, that is what lets us measure the alert effect, and the regular thermal effect. Used for prediction and explaining past history, for hourly regional level

KEY RESULT

The alert effect, per heatwave hour

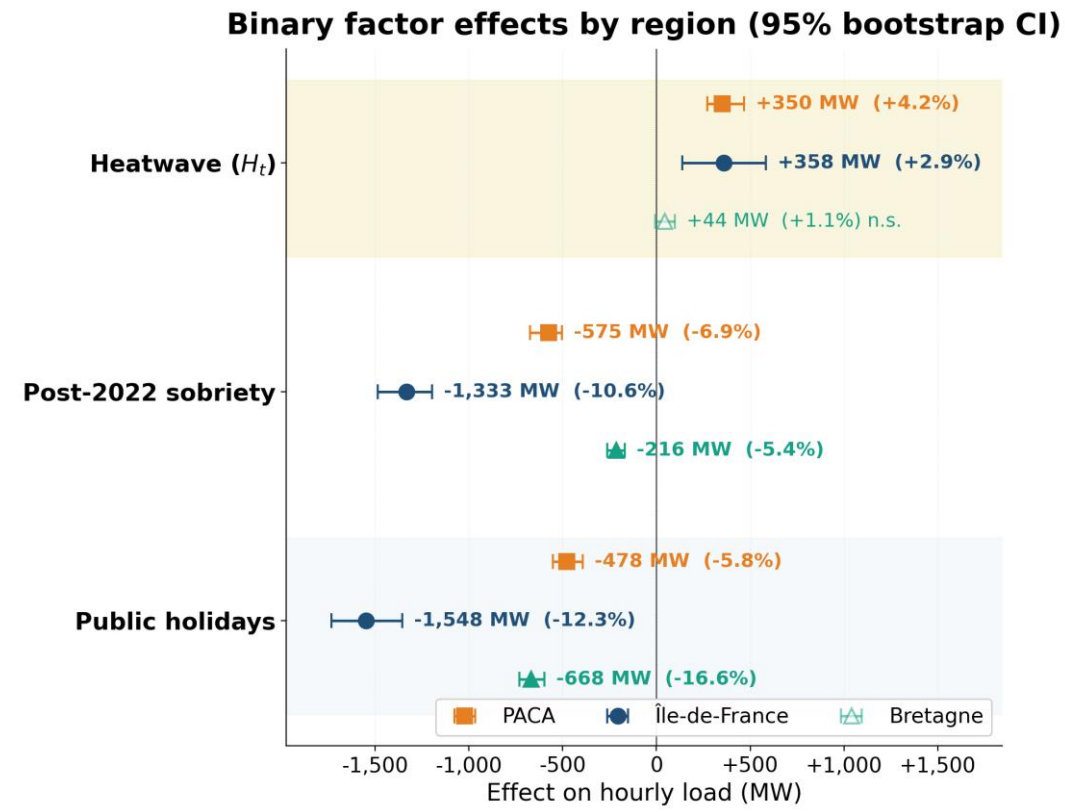


Fig. 4: Binary factor effects with 95% bootstrap CI · forest_binary_effects_pct.pdf

Insights

- PACA +350 MW and IDF +358 MW: near-equal in absolute terms
- Yet IDF is 70% larger as a power system; size alone would predict a far bigger IDF effect
- Bretagne: +44 MW, indistinguishable from zero

The alert effect tracks behavioral response: not temperature, not just grid size.

WHERE THE EXTRA DEMAND COMES FROM

Two drivers: and the mix flips by region

The everyday response to heat (thermal) plus an extra alert-driven jump: shown here over each region's biggest episode.

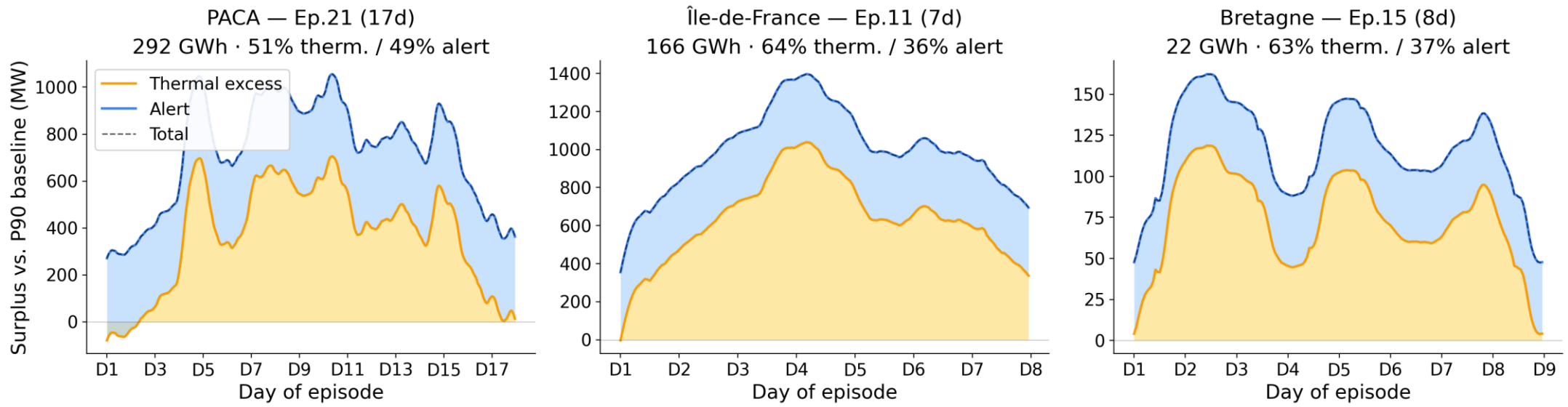


Fig. 6: Thermal (orange) vs. alert (blue) surplus over the most intense episode of each region

PACA **2,601 GWh**

62% alert-driven

Frequent episodes → demand-response

ÎLE-DE-FRANCE **1,201 GWh**

56% thermal

Fewer, intense → building insulation

BRETAGNE **179 GWh**

59% thermal

Small total → keep monitoring

ECONOMIC STAKES

338 million euros over 11 summers

TOTAL 2013-2023

338 M€

≈ 31 M€ per year on average

PACA	**≈ 221 M€**
Île-de-France	**≈ 102 M€**
Bretagne	**≈ 15 M€**

The 2022 anomaly

July 2022 · PACA
17 days
132 M€
442 €/MWh mean price

June 2019 · PACA
14 days · larger surplus
7 M€
30-90 €/MWh normal years

Same physical surplus → 20× the financial cost

Why 2022 was different
Record heatwave + European gas crisis + nuclear fleet at historic lows. The real risk: costs explode when heat and energy stress coincide.

AXIS 3 · THE GRID

Heat hits when the grid is weakest

Demand surges just as supply weakens

- Summer is the season for nuclear refuelling: many reactors are offline
- Those running may be derated when river water is too warm to cool them
- Wind output stalls under the anticyclonic 'heat dome'
- Power lines carry less as the air around them heats up

June 2026 Golfech reactor offline · spot price hit 280 €/MWh

EVEN A LOW-CARBON GRID CAN LEAN ON GAS

During the June 2026 heatwave, at the evening peak:

+10 GW

extra evening demand vs. mild June (≈ 10 reactors)

1% → 7%

share of gas in the mix at that peak, to cover cooling

Source: RTE éco2mix · analysis Bon Pote (Goldberg, Terra Nova)

Adapting: and who pays

Different regions, different levers

- **PACA** Behavioural demand-response: shift cooling off-peak via pricing or smart thermostats
- **Île-de-France** Passive cooling: insulation, solar-reflective roofs, less radiative gain
- **Bretagne** Monitor: the effect may emerge as air-conditioning spreads

Who pays?

- Heat exposure follows income, housing quality and geography: not chance
- Households without AC (often the most modest) face the highest health risk with the fewest means
- Households with AC push up peak demand: and peak prices: for everyone

Double exposure: higher physical risk and higher price exposure fall on the same households.

IN SUMMARY

Three things to remember

1

Heatwaves are the new normal

- More frequent, longer, more intense across all three regions
- They add a real surge in demand the moment an alert is declared, beyond the heat itself

2

The response is regional, and human

- Strongest where cooling is common: behaviour as much as physics
- PACA, IDF and Bretagne each need their own lever, not one national rule

3

A summer strain on the whole system

- It lands when the grid is least flexible, and bites hardest in stressed years
- Managing it means supply, demand and fairness together

Heatwaves are no longer only a weather story: they are an energy and equity story.

THANK YOU

Co-investigators Alicia Bassière · Anne Barros · Théotime Coudray · Ibtissem Khelifati
Anastasia Akakpo-Numado · Grace Domaya Nekouanodji

PowDev · Heatwaves & grid resilience
Funded by ANR · France 2030

Questions?

pepr-tase.fr/projet/powdev

Sources Bon Pote (23/06): bonpote.com/canicule-la-clim-consomme-plus-delectricite-au-gaz-que-prevu | Meteo-France (19/06): meteofrance.com/actualites-et-dossiers/actualites/canicule-une-vague-de-chaleur-sinstalle-cette-semaine | Le Monde (juin 2026) | Franceinfo (25/06): franceinfo.fr/alerte-vigilance-rouge-canicule-72-departements