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The Cooling Trap: How Europe's 2026 Heatwave is Exposing the Structural Contradiction at the Heart of the Energy Transition

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Abstract

Europe's 2026 heatwave exposed a structural contradiction at the heart of the energy transition. Extreme heat weakened low-carbon electricity supply at the same time as it increased demand for cooling. This paper examines how these two processes reinforce one another. Nuclear reactors reduced output as rivers became too warm for cooling. Hydropower declined as reservoirs fell. Wind generation weakened under persistent high-pressure systems. At the same time, millions of households relied on recently installed air conditioners during the evening, after solar generation had declined. This growing mismatch pushed Belgium's wholesale electricity price to €1,038/MWh on 24 June 2026, around ten times its typical level. This paper argues that Europe is entering a cooling trap. Air-conditioning demand is growing faster than battery storage, demand response, grid flexibility, and climate-resilient electricity supply. Countries now entering mass air-conditioning adoption may be reproducing the same structural imbalance unless cooling demand becomes a central component of energy-transition planning.

Keywords: energy transition · heatwave · electricity grid · air conditioning adoption · nuclear cooling · hydropower · battery storage · demand response · cooling trap · European grid

1. Introduction: The Grid Under Three-Sided Pressure

On 24 June 2026, Belgium's wholesale electricity price reached €1,038.25/MWh, the highest level in six years and around ten times the monthly average. The immediate causes were visible. Temperatures approached 39°C. Conventional power stations were already operating at full capacity. Millions of air conditioners purchased during the previous two to three years were switched on as

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people returned home. Demand peaked just as solar generation declined, leaving expensive gas-fired peaking plants to supply the evening load [1]. The price spike exposed a deeper structural problem. Extreme heat is weakening Europe's low-carbon electricity supply at the same time as it is increasing electricity demand for cooling. Nuclear reactors reduce output as rivers become too warm for cooling. Hydropower declines as reservoirs fall during prolonged drought. Wind generation weakens under the persistent high-pressure systems that drive heatwaves. At the same time, electricity demand rises rapidly as households increasingly rely on air conditioning. The result is a growing mismatch between when low-carbon electricity is available and when cooling demand is greatest.

This tension reflects assumptions that have shaped European electricity planning for decades. Peak demand was expected to occur in winter. Summer was the preferred period for planned maintenance. Cooling was considered a seasonal convenience rather than essential infrastructure. Climate change is overturning all three assumptions simultaneously. In this paper, I examine the emerging cooling trap created by these changes. I address three questions. First, how does extreme heat reduce the availability of low-carbon electricity? Second, why is cooling demand now increasing faster than the infrastructure needed to supply it cleanly? Third, what changes in storage, demand response, climate-resilient generation, and grid flexibility are required if Europe is to support widespread household air-conditioning during prolonged heatwaves? I, then, argue that Europe is confronting a structural contradiction in the energy transition. The same climate change that increases the need for low-carbon electricity is simultaneously making low-carbon electricity harder to supply. Thus, unless cooling demand becomes an explicit part of transition planning, this contradiction is likely to intensify as heatwaves become more frequent and air-conditioning adoption accelerates.

2. How Heat Weaken the Low-Carbon Grid: The Supply Side

Public discussion of heatwaves and electricity usually focuses on demand. Millions of households switch on air conditioners at the same time, increasing pressure on the grid. That explanation is correct but incomplete. The 2026 heatwaves also exposed a supply-side problem. Extreme heat simultaneously reduced output from several low-carbon electricity sources. The technologies expected to support decarbonisation became less reliable precisely when electricity demand was highest.

2.1. Nuclear power and the river cooling constraint

France's 57 nuclear reactors generate around 70% of the country's electricity. Most depend on river water for cooling, and discharge temperatures are regulated to protect aquatic ecosystems. At Golfech, the Garonne must remain below 28°C after cooling water is returned. At Nogent-sur-Seine, the Seine cannot increase by more than 3°C and must remain below an average of 28°C [2,3]. These limits became binding during the June 2026 heatwave. On 22 June, EDF shut down Unit Two at Golfech as the Garonne approached the regulatory threshold. The company described the shutdown as a precaution rather than a reactor safety issue [4]. By 25 June, EDF had reduced output from three reactors by around 4 GW, equivalent to about 6% of French nuclear capacity and 7% of national midday demand. Output at Nogent-sur-Seine was also reduced [3, 5].

This is no longer an isolated event. More than 7 GW of French nuclear capacity was unavailable during the July 2025 heatwave, exceeding Ireland's entire electricity-generating capacity [4]. EDF's 2026 climate vulnerability assessment estimates that adapting its nuclear and hydropower fleet will require approximately €600 million annually for the next 15 years [4]. The assessment recognises that climate

change is reducing the reliability of these assets. Yet planning assumptions have changed more slowly. Spring maintenance schedules still reflect a climate in which severe summer heat was uncommon. During the June 2026 event, Unit One at Golfech was already offline for maintenance when extreme temperatures forced Unit Two to shut down [4].

2.2. Hydropower and the drought connection

Heatwaves also reduce hydropower. The same high-pressure systems that produce extreme heat suppress rainfall and lower reservoir levels. May 2026 was the driest on record across several European regions, with parts of France receiving only one-half to two-thirds of normal rainfall. Reservoirs entered summer already depleted. The consequences were immediate. During the first five months of 2025, heat and drought reduced European hydropower generation by 13% compared with the previous year [4]. Similar conditions contributed to the severe European heatwave of 2022. High-pressure systems also weakened wind generation. During the 2025 heatwave, below-normal wind output was forecast across Germany, France, Italy, and Spain [7]. These events share the same driver. Heat reduces nuclear output through warmer rivers, hydropower through lower reservoirs, and wind generation through atmospheric stagnation. The correlation is thermodynamic rather than coincidental. All three constraints emerge during the same weather system and coincide with peak cooling demand.

2.3. Thermal generation and grid infrastructure under heat stress

Residual fossil-fuel generation is also vulnerable to extreme heat. Higher ambient temperatures reduce gas turbine efficiency and impair cooling systems. During the June 2026 heatwave, five gas-fired power stations in the United Kingdom reduced output by around 2.5 GW [8]. Electricity networks face similar constraints. High temperatures increase thermal stress on transmission infrastructure and reduce the capacity of power lines. Repeated blackouts occurred in Turin during late May 2026, while several European system operators warned of transmission constraints as electricity demand and ambient temperatures increased simultaneously [6].

2.4. The solar contribution and its temporal limits

Solar generation appears to offer a solution. Heatwaves usually occur under clear skies, allowing photovoltaic systems to operate at high output. During the 2025 heatwave, German solar generation reached almost 50 GW and supplied between 33% and 39% of electricity during peak daytime hours [9]. The limitation is not generation but timing. Solar output peaks between late morning and mid-afternoon. Cooling demand peaks several hours later, typically between 18:00 and midnight, when buildings release stored heat, and people return home. Belgium's price spike occurred at 20:45, long after solar output had declined.

This timing mismatch is becoming increasingly important. In 2025, daily electricity price spreads exceeded €400/MWh, creating strong incentives for energy storage to shift electricity from midday to evening demand [9]. ACER's 2026 monitoring report similarly concludes that growing solar deployment is widening the gap between low midday prices and expensive evening peaks, increasing the importance of battery storage and demand-response systems [10]. Therefore, solar solves only part of the problem. It supplies abundant electricity during the day but cannot meet rapidly growing evening cooling demand without large-scale storage and greater system flexibility. As solar capacity

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expands, the cooling trap becomes less a problem of electricity generation than one of electricity timing.

Key mechanism: The defining mechanism of the 2026 heatwaves was a triple supply squeeze. Nuclear output fell as river temperatures exceeded cooling thresholds. Hydropower declined as drought depleted reservoirs. Wind generation weakened under the same high-pressure system that produced the heatwave. These constraints coincided with the evening peak in cooling demand, after solar generation had largely ceased.

3. What is Changing on the Demand Side: The Cooling Transition

The supply constraints described above are only half of the story. Demand is changing even faster. Unlike the supply side, the direction of change is clear. Europe is entering a rapid cooling transition. Air-conditioning adoption is accelerating across the continent, while the electricity system is adapting much more slowly. The result is a widening gap between cooling demand and the infrastructure needed to supply it cleanly.

3.1. The Baseline and the Break

European electricity systems were designed for a different climate. Demand was expected to peak in winter, while summer provided a period for planned maintenance. Cooling was expected to remain a minor component of electricity demand. However, data show that this assumption is changing rapidly. Household air-conditioning ownership averaged only 20% across Europe in 2022, compared with 76% in North America and 47% in the Asia-Pacific region [11]. Within Europe, adoption was even lower. Fewer than 5% of households in the United Kingdom and around 3% in Germany owned an air conditioner in 2022 [8].

Growth has since accelerated. Air-conditioning ownership in Germany increased from about 13% in 2023 to almost 19% in 2024, while another 19% of households planned to purchase a unit [12]. Agora Energiewende estimates that increasing penetration from 19% to 35% could add up to 12 GW of electricity demand during heatwaves, roughly equivalent to the output of ten coal-fired power stations [12]. A German Institute of Urban Affairs study reaches a similar conclusion, projecting an increase of more than 12.9 GW in peak demand under 35% household penetration, with urban hotspots exceeding 5 MW per square kilometre [13]. Air-conditioning ownership in the United Kingdom also approximately doubled between 2022 and 2026 [8,14]. Reflecting this trend, the European air-conditioning market is projected to expand from US$26.5 billion in 2025 to US$46.4 billion by 2034 [15]. These trends point to a structural shift. Europe is moving from a winter-peaking electricity system towards one in which prolonged summer heat increasingly determines peak demand.

3.2. The Adoption curve and the Lock-in Problem

For electricity planning, the critical issue is not current ownership but the speed of adoption. Air conditioners are long-lived capital goods. Once installed, they remain in use for many years and permanently increase electricity demand during hot weather. Heatwaves reinforce this process. As extreme temperatures become more frequent, cooling changes from a discretionary purchase to a necessity. Each heatwave that threatens health, disrupts sleep, reduces productivity, or makes homes difficult to occupy increases the incentive to install air conditioning. The International Energy Agency

(IEA) projects that the number of air-conditioning units across the European Union will reach 275 million by 2050, more than double the 2019 level [16]. Without major efficiency improvements, global electricity demand for cooling is expected to more than triple by mid-century, reaching a level comparable with the current electricity consumption of China and India combined [17].

This creates a reinforcing feedback loop. Heat drives air-conditioning adoption. Greater cooling demand increases electricity consumption and, where supplied by fossil-fuel generation, raises greenhouse gas emissions. Those emissions contribute to further warming, increasing future cooling demand. Air-conditioning systems also reject heat into the surrounding environment, intensifying urban heat islands and making heatwaves more dangerous, particularly at night. This is the cooling trap. The problem is not the technology itself. Air conditioning saves lives during extreme heat and will become increasingly important as the climate warms. The challenge is that adoption is accelerating faster than battery storage, demand response, grid flexibility, and climate-resilient electricity supply. Unless these systems expand at a similar pace, every heatwave will widen the gap between cooling demand and the low-carbon electricity needed to meet it.

Adoption velocity: In Germany, household air-conditioning ownership nearly doubled within a year, increasing from 13% in 2023 to 19% in 2024. In the United Kingdom, ownership approximately doubled between 2022 and 2026. In France, evening electricity demand peaked at 25% above the seasonal average during the 2025 heatwave, despite household air-conditioning penetration of only 20%. The implication is clear: if household penetration reaches 35–40%, evening demand peaks are likely to become unmanageable without battery storage, demand-response programmes, and grid-flexibility infrastructure that do not yet exist at the required scale.

4. The Solar-Evening Gap and Why Storage is the Pivot

Sections 2 and 3 identify two sides of the same problem. Extreme heat reduces the availability of low-carbon electricity while simultaneously increasing demand for cooling. The critical issue is timing. Solar generation peaks during the middle of the day, whereas cooling demand peaks several hours later, after solar output has declined. Under normal conditions, electricity systems can manage this mismatch. However, during the 2026 heatwaves, it became a structural vulnerability. The triple supply squeeze coincided with rapidly growing evening cooling demand, exposing the limits of a transition built around electricity generation but not electricity timing.

Battery storage provides the clearest response to this problem. It allows surplus solar electricity generated during the day to be stored and released during the evening cooling peak, reducing dependence on expensive and carbon-intensive peaking generation. The economics are increasingly favourable. Ember estimates that electricity supplied through solar or wind combined with battery storage costs around €64/MWh in Italy, compared with an average of €111/MWh for gas-fired peaking generation in 2025 [18].

Experience elsewhere suggests that deployment can rapidly reshape electricity systems. In California, batteries supplied almost 20% of evening peak demand by September 2025, compared with only 3% four years earlier. Over the same period, the contribution of fossil-fuel generation during the evening peak fell from 44% to 34% [18]. Therefore, storage changes more than generation costs. It changes when renewable electricity is available. Europe is expanding battery deployment, but the critical

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question is whether it is expanding fast enough. Germany, Italy, Bulgaria, the Netherlands, and Spain accounted for more than 60% of new EU battery capacity in 2025 [7]. SolarPower Europe projects that the European battery market will grow by 500% between 2024 and 2029 [19], while total EU storage capacity could reach 603 GWh by 2030 [20].

The uncertainty lies on the demand side. Germany's projected increase from 19% to around 35% household air-conditioning penetration would add approximately 12.9 GW to evening peak demand [13]. Current adoption rates suggest this level could be reached early in the next decade. The central question is therefore no longer whether Europe is deploying storage, but whether storage deployment is keeping pace with cooling adoption. At present, the evidence suggests that the adoption curve is moving faster than the infrastructure curve.

4.1. Interconnection as insurance

Storage alone cannot eliminate the risks created by widespread heatwaves. Stronger electricity interconnection provides a second layer of resilience. Heatwaves normally move across Europe over several days rather than affecting every country simultaneously. During the 2025 event, the highest temperatures shifted from Madrid to Paris, Berlin, and Warsaw [9]. Interconnected electricity markets allow surplus generation in one region to support another as these demand peaks migrate. The April 2025 Iberian blackout illustrated the same principle in reverse. Without sufficient transmission capacity, renewable electricity produced in one region cannot be delivered to neighbouring regions experiencing shortages [21]. The European Union's Ten-Year Network Development Plan recognises this challenge. However, delivery has consistently lagged planned investment, leaving interconnection weaker than the transition increasingly requires.

4.2. Demand Response: The Underutilised Lever

Storage and interconnection address electricity supply. Demand response addresses electricity timing. Many cooling loads are flexible. Buildings can be pre-cooled before the evening peak. Electric vehicles, water heating, and other flexible appliances can shift consumption towards periods of abundant solar generation. These measures reduce peak demand without requiring additional generation capacity. Despite this potential, deployment remains limited. ACER's 2026 monitoring report identifies regulatory barriers and underdeveloped electricity markets as major obstacles to wider participation in demand-response programmes across the European Union [10]. Consumer incentives remain weak. In Belgium, dynamic electricity tariffs are used by fewer than 1% of households, meaning that the June 2026 price spike was largely invisible to most consumers [1]. While fixed tariffs protect households from short-term price volatility, they also reduce incentives to shift demand, install household batteries, or participate in flexibility markets. Therefore, the 2026 heatwaves reveal that the next phase of the energy transition is not primarily about adding more renewable generation. It is about matching the timing of electricity supply with the timing of electricity demand. Storage, interconnection, and demand response are no longer complementary technologies. Together, they form the infrastructure that determines whether rapidly growing cooling demand can be met without increasing dependence on fossil-fuel generation.

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5. What the Evidence Shows and What it Does Not

Several conclusions are now well supported. First, the triple supply squeeze is no longer an isolated phenomenon. Nuclear output declines as river temperatures exceed cooling thresholds. Hydropower falls as drought reduces reservoir levels. Wind generation weakens under the same high-pressure systems that produce heatwaves. Even gas-fired generation loses efficiency under extreme heat. These constraints have been observed across multiple European heat events and represent structural features of a low-carbon electricity system under climate stress rather than anomalies of any single summer.

Second, the cooling transition is clearly underway. Germany's increase in household air-conditioning ownership from 13% to 19% within a year, the doubling of ownership in the United Kingdom, the unusually high evening electricity demand observed in France despite relatively low air-conditioning penetration, and the IEA's projection of 275 million air-conditioning units across the European Union by 2050 all point in the same direction. The precise pace of adoption remains uncertain, but its trajectory does not.

The main uncertainty concerns the speed of the infrastructure response. Battery storage, demand response, and electricity interconnection are expanding rapidly. Whether they will expand quickly enough to keep pace with cooling demand is less certain. The projected 603 GWh of EU battery capacity by 2030 is substantial, but its adequacy depends on future air-conditioning adoption, demand-response participation, and cross-border electricity flows. These factors cannot yet be estimated with confidence.

However, the overall pattern is clear. The solar-evening gap is widening. Heat increasingly constrains low-carbon electricity supply while simultaneously increasing cooling demand. Air-conditioning adoption continues to accelerate. Therefore, the question is no longer whether these forces will interact, but whether Europe can deploy storage, grid flexibility, and demand-response systems quickly enough to prevent the cooling transition from becoming a new source of fossil-fuel dependence.

6. Implications for Transition Planning

6.1. The Sequencing Problem

Europe's energy transition has been built mainly around expanding low-carbon electricity supply. Solar and wind deployment has accelerated, fossil-fuel generation has gradually declined, and storage and interconnection have been expected to manage variability. The 2026 heatwaves suggest that this sequencing is incomplete. Cooling demand is growing faster than the flexibility infrastructure needed to support it. This creates a risk of technological lock-in. As air-conditioning adoption increases, the evening cooling peak becomes a permanent feature of summer electricity demand. If battery storage and demand-response systems are not deployed before this demand becomes structurally embedded, system operators will continue to rely on gas-fired peaking plants to maintain reliability. Therefore, short-term operational responses may create long-term dependence on fossil-fuel generation during the hours when electricity demand is highest. The Belgian price spike illustrates both the challenge and the opportunity. A battery charged at €50/MWh and discharged at €1,038/MWh could earn a gross arbitrage margin of almost €1,000/MWh in a single cycle. These price signals should encourage

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rapid investment in storage. However, investment depends not only on market incentives but also on planning systems, grid-connection procedures, and electricity-market rules. At present, these institutional responses appear to be evolving more slowly than cooling demand itself.

6.2. Nuclear Climate-proofing as a Priority

The French experience highlights a broader challenge for river-cooled electricity systems. Environmental regulations governing cooling-water discharge were developed under climatic conditions in which prolonged periods of exceptionally warm rivers were uncommon. That assumption is becoming increasingly difficult to sustain. EDF estimates that adapting its nuclear and hydropower assets to a warmer climate will require around €600 million annually over the next 15 years [4]. This shifts the policy debate from whether climate adaptation is necessary to how it should be financed and incorporated into long-term electricity planning. The implications extend beyond individual power stations. Capacity adequacy assessments should account for the declining reliability of river-cooled generation during extreme heat. Otherwise, electricity systems risk overestimating dependable summer capacity while underestimating the value of storage, demand response, and interconnection. Planning assumptions developed for twentieth-century climate conditions require revision as heat extremes become more frequent.

6.3. Transferability beyond Europe

The lessons extend beyond Europe. The structural vulnerabilities identified here do not arise from Europe's particular electricity mix but from the interaction between climate change, cooling demand, and electricity-system design. The solar-evening gap, river-cooling constraints, limited demand-response capacity, and storage deployment lag are likely to emerge wherever rapidly increasing air-conditioning adoption coincides with decarbonisation. Europe demonstrates one possible pathway, but similar pressures are already developing across South Asia, sub-Saharan Africa, Latin America, and other regions where cooling demand is growing rapidly.

Many of these countries face even greater challenges. Urbanisation is faster, temperatures are often higher, electricity networks are less resilient, and balancing resources are more limited than in Europe. The cooling transition may therefore occur under conditions of greater structural vulnerability. The central lesson is one of sequencing. Storage, demand response, and grid flexibility should expand before cooling demand becomes structurally embedded, not afterwards. Once evening cooling peaks become established, electricity systems risk locking into fossil-fuel generation precisely when deep decarbonisation requires the opposite. Europe's experience therefore provides an early warning of a broader transition challenge that many countries have not yet fully encountered.

7. Conclusion

On 24 June 2026, the Belgian day-ahead electricity market reached an evening peak of €1,038.25/MWh. That price spike was not simply the result of a hot day. It exposed a gap in transition planning. Air-conditioning adoption is accelerating faster than the battery storage, demand-response systems, grid flexibility, and climate-resilient generation needed to supply rising cooling demand with low-carbon electricity. The evidence points to a structural rather than temporary problem. Extreme

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heat increasingly constrains nuclear, hydropower, and wind generation at the same time as it drives rapid growth in electricity demand for cooling. Meanwhile, household air-conditioning ownership continues to rise across Europe, and the IEA projects global cooling-related electricity demand to more than triple by 2050.

The cooling trap emerges where these two trends intersect. Climate change increases the need for cooling while simultaneously reducing the availability of low-carbon electricity. If the resulting evening demand is met by fossil-fuel generation, adaptation today reinforces the conditions that increase cooling demand tomorrow. Therefore, the central challenge is one of sequencing. Storage, demand response, and grid flexibility must expand as rapidly as cooling demand, not years after it has become structurally embedded. Whether Europe can close this gap before the cooling transition locks in a new source of fossil-fuel dependence remains an open question.

> *"The European experience provides a lesson. Build storage and demand response before cooling demand becomes a major system challenge, not after infrastructure starts falling behind. "*

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