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How Hourly Clean Energy Matching Cuts the Costs and Emissions of Spain's Data Centre Buildout

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An open-source, replicable and fully transparent study by two independent non-profits with no commercial interest in the outcome of this policy. It received no external funding.

Contents

Contents **2**
Executive summary **2**
1. An overview of the Decree **5**
1.1 A wave of new demand 5
1.2 What the draft Royal Decree proposes 5
1.3 Why the government proposed it 6
1.4 Why hourly matching, not annual matching 7
2. An Open-Source modelled Analysis **7**
2.1 How the analysis works 7
2.2 Finding (A): Without a policy, data centres raise emissions and costs for everyone 9
2.3 Finding (B): 80% hourly matching averaged over a year delivers most of the benefit, at lower cost than doing nothing 10
2.4 Finding (C): Hourly clean energy matching is cost effective 13
2.5 Finding (D): Design matters. A floor in every hour is more costly than necessary and challenging to implement 16
2.6 Finding (E): Impacts grow with the data centre buildout 18
2.7 Study Limitations 20
3. Recommendations for policymakers **22**
FAQ **23**
About the model 23
About the policy 23
About the system 24
Annex **26**
A1. Model validation 26
A2. Glossary 26
A3. Other Cases Run 26
A4. Reproducibility 27
Declaration of Interests **28**
Author bios **28**

Executive summary

As the development of data centres to power digital services and artificial intelligence accelerates, a core challenge is ensuring that the massive new electricity demand can be served without significantly increasing carbon emissions, fossil import reliance and electricity prices. Spanish policymakers have answered this question with a recent proposal to require data centres to procure new renewable energy that matches their hourly electricity demand.

To address these risks, the government proposes to require data centres to meet a minimum of 80% of each hour's load with renewable energy. Those that fail to comply would face penalties and potentially loss of grid access for repeated non-compliance. On 26 October 2026, the government sent a new version of the policy to the Council of State (El Economista). The new version introduces an optional transition period for data centres that accept automatic curtailment, with lower matching requirements during peak hours.

In response, data centre industry representatives have claimed that the new rules are too onerous, impossible to achieve, and exorbitantly expensive. The data centre association Spain DC has said that "the sum of requirements could turn this regulation into a veto on the sector" and that "the design is unworkable," warning that €9 billion of planned investment by three of its members is at risk (EFE, 11 Sep 2026; Spain DC).

We built an open model of Spain's electricity system to test the government's proposed renewable energy rules for data centres. We find that **hourly renewable matching is essential**. It prevents most of the emissions and price increases that new large data centres would otherwise cause, which confirms the core thesis of the proposal. The draft's design of the rule, however, is costly and hard to implement: it requires at least 80% matching in every single hour of the year. **Hourly matching of 80% or 90%, measured as an annual average, delivers most of the same benefits.** It is also much cheaper, for data centre operators and the electricity system alike, than letting data centres connect with no rules on how they are powered. Finally, it cuts emissions more, and at lower cost, than the government's proposed transition rules for peak-demand periods.

The **key findings** of the analysis are:

1. No policy means significant carbon emissions and electricity price increases for Spanish consumers. With no procurement rule, a 500 MW data centre is largely served at the margin by gas. Spanish power-sector emissions rise by about 1.1 Mt CO2 a year (+6%), gas burned for power increases by 5.3 TWh (+10%), and the average spot price every Spanish consumer pays rises by about 1.30 €/MWh, an increase of 1.9% on the wholesale power price from a single data centre.

2. 80% & 90% hourly matching, measured as an annual average, significantly mitigates emissions, gas generation, and electricity price increases. For the same 500 MW data centre, 80% hourly matching removes 79% of the emissions increase and 78% of the electricity price increase relative to no policy. It also moves the bill. With no policy, serving the

data centre costs the Spanish system €289 million a year more in fuel and running costs. The data centre pays for its own electricity, but because gas sets the price more often, every other consumer pays about 1.3 €/MWh more, roughly €300 million a year across Spanish demand. With 80% hourly matching on average, the extra fuel cost falls to €62 million and the price effect to about 0.3 €/MWh, because the data centre covers most of its own supply with €160 million a year of new wind and solar. Overall, the total system cost is €67 million a year lower than with no policy. We also model 90% hourly matching and find that it can control emissions and price increases even more effectively, while still lowering overall system costs. 80% and 90% average hourly matching also cut more emissions than the government's two proposed transition rules (P1 and P2), respectively, at the same or lower total cost, and a smaller share of that cost falls on other consumers.

3. 80% and 90% hourly clean energy matching is significantly cheaper for data centre operators. 80% hourly matching can be achieved with a combination of wind and solar PPAs at a cost of 54 €/MWh, 26% cheaper than the cost of grid electricity in the no policy case (73 €/MWh). 90% hourly renewable energy matching is 14% cheaper. We therefore recommend an hourly matching score, measured as an annual average, that starts at 80% and rises to 90% by the end of the draft's five-year transition.

4. Requiring 80% in every single hour, as the decree is currently drafted, adds unnecessary expense and burden to policy design. To meet 80% in the worst winter hours, the data centre must significantly oversize its procurement relative to its load and curtail 30% of the generation it procures. As a result, electricity costs under this scenario rise to 93 €/MWh, and total system cost is €106 million a year higher than with no policy at all: the extra fuel burned in Spanish plants disappears entirely, but the data centre's €403 million a year in contracts outweighs that saving. An 80% or 90% annual average captures most of the emissions and price benefit at a fraction of this cost.

5. The stakes grow with the size of the buildout, as do the benefits of hourly matching. With no policy, a 6,000 MW buildout would raise Spanish power-sector emissions by 14.3 Mt CO2 a year (+81%) and the spot price by 10.30 €/MWh (+14%). With 80% hourly matching on an annual average, the emissions increase is 77% smaller, the price increase 88% smaller, and the system cost €470 million a year lower than with no policy. Hourly matching also acts as a hedge both for data centre operators (reducing exposure to gas-driven volatility) and for the system (reducing gas use, emissions and electricity prices relative to the no-policy scenario).

Our Conclusion: The **Spanish government is right:** new data centre demand must bring new clean supply, matched to the hours it consumes. The rules **should keep hourly matching and additionality, but measure the target as an annual average** rather than a floor in every hour, **starting at 80% and rising to 90% by the end of the draft's five-year transition.** This design cuts procurement costs for data centres and makes compliance simpler to verify. It protects consumers from most of the price increase and avoids most of the extra emissions and gas imports that data centres would otherwise cause. Faster permitting and grid connection for would help meet goals sooner and at lower cost.

1. An overview of the Decree

1.1 A wave of new demand

Spain is one of Europe's fastest-growing data centre markets. Its 2024 Artificial Intelligence Strategy foresees about 2.5 GW of computing capacity by 2030, which the government estimates would need 3.5 to 4 GW of electricity demand. According to Red Eléctrica's access map, data centres hold **6.33 GW of granted transmission access**, 34% of all access granted to new demand (pv magazine, 2 Oct 2026). The government reports **more than 12 GW of access and connection rights** granted to data centres since 2021 (MITECO, Aug 2026).

Data centres are large and run almost flat, around the clock. For context, a single 500 MW campus consumes about 4.4 TWh a year, close to 2% of Spanish electricity demand. A flat load of this kind needs power at night and in winter, when Spanish wind and solar output is lowest and gas-fired plants set the price.

1.2 What the draft Royal Decree proposes

The latest draft of the Spanish government's policy, sent to the Council of State on 26 October 2026, proposes the following requirements for data centres of 10 MW or more:

- **Additionality (annual volume).** 80% of consumption must be covered by renewable electricity from *new* Spanish installations, including storage, through self-consumption or long-term contracts (PPAs). The plants must have entered service no more than 36 months before the data centre starts operating. Until the end of 2028, data centres have six months after signing their grid-access contract to comply.
- **Hourly correlation.** In **every hour**, at least 80% of consumption must be backed by renewable electricity generated in that same hour, with discharge from associated storage counted as renewable. The system operator checks compliance each month.
- **Enforcement** through surcharges on network tariffs and system charges. Missing the hourly test adds 10% to 100%, depending on the month's average hourly shortfall below the hourly requirement, plus 10 percentage points for each further consecutive year of non-compliance. Missing the additionality requirement adds 100% to 500%. Grid access can be withdrawn after five consecutive years with additionality below 60% or with 20% or more non-compliant hours.
- **Transition regime.** For five years from entry into force, data centres can join the automatic load-reduction scheme (SRAP), and accept curtailment to zero on the system operator's signal. In return, less stringent hourly matching requirements apply, only in peak periods:

- **Until 31 December 2028:** a minimum of 60% of consumption in P1 hours (9–14h and 18–22h on weekdays in January, February, July and December). This corresponds to about 9% of hours.
- **From 1 January 2029 to the end of the transition:** a minimum of 70% of consumption in P1 hours and 60% in P2 hours (8–9h, 14–18h and 22–24h on those days, plus 9–14h and 18–22h on weekdays in March and November). This corresponds to about 20% of hours in total.

1.3 Why the government proposed it

In the original draft of the policy, published on 27 August 2026, the government sets out its reasoning. Since December 2023, it notes, the transmission system operator has granted data centres more than 6 GW of grid access, and around another 6 GW has been granted on distribution networks since 2020, more than even the most ambitious deployment forecasts. Citing inflated energy prices due to the conflict in the Middle East, it notes that large new loads not matched by new renewables would mean more gas burned for power in tight markets, with higher electricity costs for all consumers and a weaker incentive to electrify.

It also notes the impacts of the “essentially flat” load from data centres: "Consequently, an increase in demand of this kind can raise the need for generation and firm capacity, which, in a marginal-pricing electricity market such as Spain's and Europe's, and unless a specific framework is adopted, means greater use of gas as the marginal technology and, with it, higher electricity prices for all consumers." (Section 1, Page 3 of the original draft Royal Decree)

Therefore, the policy rests on a simple and sound idea: **additional demand should bring additional clean supply, matched to the hours when it actually consumes.**

- **Emissions.** Spain's average grid mix is already relatively clean. But what matters for a *new* load is what changes in the system to serve it. In most hours of low wind and sun, that is a gas-fired plant. A data centre that buys "average" grid power or annual renewable certificates can still drive substantial new gas generation.
- **Prices for everyone else.** Extra flat demand pushes more expensive plants onto the margin in more hours. This raises the wholesale price for all consumers, households and industry included.
- **Energy security.** More gas generation means more imported gas and related exposure to volatile gas markets.
- **A useful grid asset.** Done right, a matching requirement turns new load into a source of financing for new wind, solar and storage. It also hedges the data centre against volatile wholesale prices.

1.4 Why hourly matching, not annual matching

Most corporate clean energy claims today rely on **annual matching**: buying enough renewable energy or certificates over a year to equal annual consumption. Annual matching ignores *when* the clean megawatt-hours are produced. A data centre can "match" its night-time consumption with surplus midday solar that it never physically uses. In a system where solar is already abundant at midday, that surplus is often curtailed.

Hourly matching (also called 24/7 carbon-free energy, or 24/7 CFE) counts clean energy only in the hour it is produced and consumed. A growing body of research, including Riepin & Brown (2024), finds that hourly matching leads buyers to procure complementary resources such as wind, storage and other firm clean supply. It also reduces system emissions far more than annual matching. EU rules already apply temporal correlation for renewable hydrogen (Delegated Regulation (EU) 2023/1184), moving to hourly matching from 2030. Hourly-granular certificates are being developed and standardised. All power markets in Europe settle at sub-hourly granularity, so the data to implement hourly matching is available.

The question for Spain is therefore not *whether* to match hourly, but *how*. In particular, should 80% be required in every hour, or on average across all hours of the year? This report answers that question with an open model.

2. An Open-Source modelled Analysis

2.1 How the analysis works

The model builds on PyPSA-Eur, an open model of the European power system built with the PyPSA framework. It represents Spain's 2025 electricity system hour by hour over a full year, with nine Spanish regions and links to France and Portugal. It is validated against Red Eléctrica's actual 2024 data. We then add a new data centre and let it buy electricity under each policy: no matching, the draft's every-hour rule, 80% or 90% hourly matching on an annual average, and the transition rules for peak periods. In each case the model picks the cheapest portfolio of new wind, solar and storage contracts that meets the rule, and runs the whole system around it. We compare system costs, CO2 emissions, wholesale prices and the data centre's own costs with a system that has no data centre. The reference case is a 500 MW data centre in Aragón, Spain's data centre hub. We also test buildouts of 2,000 to 6,000 MW.

Using the PyPSA Europe open optimisation model for the European energy system, we built a model of today's Spanish power system to test the decree and alternative designs. The table below shows the key features of the model:

Feature	Approach
Model	PyPSA-Eur v2026.09, an open-source European power-system model
Geography	15 regions: 9 in Spain (8 mainland plus the Balearics), 4 in France, 2 in Portugal. France's other borders are fixed to measured 2024 flows
Power fleet	Spain's 2025 generation fleet, calibrated to published national data and held fixed
Weather and time	Weather year 2024, full year at hourly resolution (8,760 time steps)
Validation	Back-cast of 2024 compared with Red Eléctrica's reported generation, emissions and flows; all validation gates pass after documented, cited corrections
Costs	Open technology-cost data (technology-data v0.15.0, EUR 2025); 2025 market prices for gas, coal and CO2
Data centre	A flat load in Aragón: 500 MW (4.38 TWh/yr) in the main case; 2,000, 4,000 and 6,000 MW in the buildout-size analysis (section 2.6)
Procurement	The model chooses the least-cost portfolio of new onshore wind, fixed and tracking solar, and batteries, anywhere in mainland Spain. Surplus output is not sold to the grid (a conservative assumption; see section 2.7)
Measures	Change in Spanish system cost, CO2, gas burn and spot prices against the same system without the data centre

Every input is cited to a primary source, and every figure can be reproduced from the public repository. The study authors received no funding from any government, company or interest group for this work. We compare six cases:

Case	Rule
No policy	The data centre buys all its electricity from the grid or covers it with certificates or contracts from existing resources, which add no new supply
Hourly 80% on average	Hourly matching, but the 80% is measured over the whole year: matched energy summed over all hours ≥ 80% of consumption
Hourly 90% on average	As above, with a higher target: matched energy summed over all hours ≥ 90% of consumption
Transition Rule 2026	First stage of the revised draft's optional phase-in (to end-2028): at least 60% of consumption backed in each P1 hour; all other hours unconstrained.
Transition Rule 2029	Second stage (2029 to the end of the five-year transition): at least 70% of consumption backed in each P1 hour and 60% in each P2 hour; all other hours unconstrained.
Decree: 80% every hour	At least 80% of consumption from its own new PPAs and batteries in every hour (the draft decree)

What the model does. The model is a least-cost optimisation of the power system over a full year. For every hour, it decides how much each existing power plant, storage unit and cross-border link should produce or move to meet demand in each region at the lowest total cost, within the physical limits of each plant and of the transmission network. Plants are dispatched in order of their running cost (fuel, carbon price and operating cost), so the most expensive plant needed in each hour sets the spot price.

In each policy case, the model adds the data centre to this system. In the matching cases, it also chooses how much new wind, solar and battery capacity the data centre contracts, and where in Spain, so that the matching rule is met at the lowest total cost. The rule is entered as a constraint: either at least 80% of the data centre's consumption in every hour (the decree), or at least 80% (or 90%) of its consumption summed over the year (the annual average). The model optimises the dispatch of the whole system and the data centre's procurement together.

Each case is then compared with the same system without the data centre. The difference shows what the data centre causes: extra emissions, extra gas burned, changes in spot prices and extra system cost. The rest of the power fleet is held fixed at 2025 levels. The model does not build new conventional plants, and no other new renewables are added beyond those the data centre contracts.

2.2 Finding (A): Without a policy, data centres raise emissions and costs for everyone

Adding a 500 MW data centre to today's Spanish system with no procurement rule leads to:

- **+1.1 Mt CO2 per year**, a 6.0% increase in Spanish power-sector emissions (baseline 17.8 Mt).
- **+5.3 TWh of extra gas burned** in Spanish power plants each year, a **10%** increase.
- **+1.3 €/MWh on the average spot price** paid by all other Spanish consumers (+1.9% on a 71.9 €/MWh baseline).
- **+€289 million per year** in Spanish system cost. All of it is extra fuel and operating cost, which flows through to the market.

As shown in Figure 2, gas-fired plants supply most of the new load (about 3.0 TWh of the 4.4 TWh of electricity). The rest comes mainly from imports (0.6 TWh), higher nuclear output (0.3 TWh) and less curtailment of existing solar. The extra electricity therefore comes largely from **existing** gas plants running for more hours. The model holds the power fleet fixed at today's level and does not build new gas plants. As a result, the change in system-level emissions in the no-policy case, including the impacts in neighbouring Portugal and France, is 294 g CO2/kWh of new data centre consumption, about **4 times** the average grid emissions rate of 71 g/kWh (Figure 3).

2.3 Finding (B): 80% hourly matching averaged over a year delivers most of the benefit, at lower cost than doing nothing

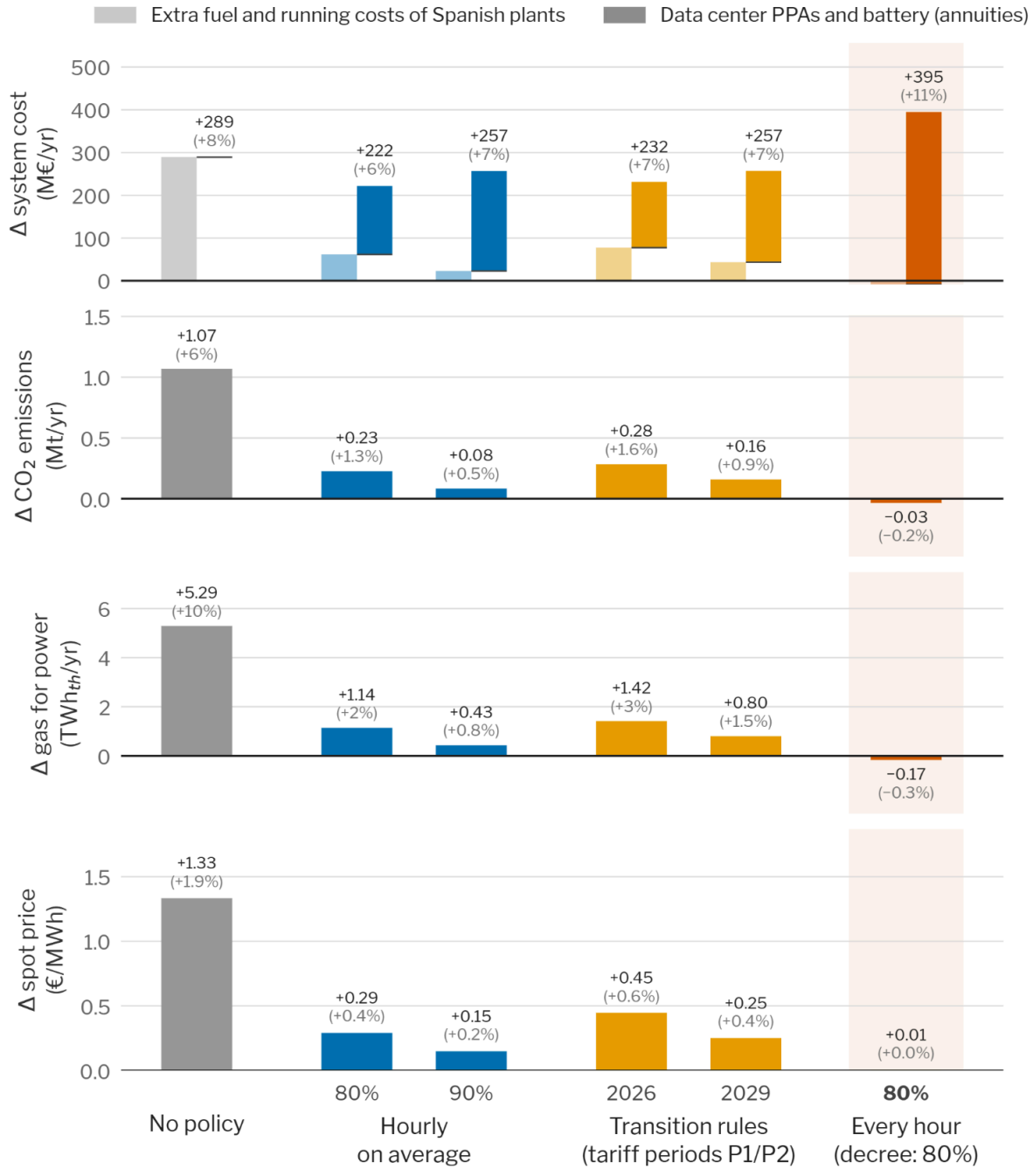
Hourly matching is critical for reducing the emissions, electricity price impacts and gas consumption associated with new data centres in Spain. Compared to the case of no policy governing data centre electricity consumption, 80% hourly renewable energy matching:

- Removes 79% of the emissions increase
- Removes 78% of the electricity price increase
- Costs 23% less for the electricity system
- Removes 79% of the increase in gas consumption

In addition to the absolute reductions in emissions and grid system impacts, Figure 1 also shows that hourly matching drives another important outcome: most of the cost of data centre buildout is borne by the data centres themselves, protecting the broader public from increased costs. Without the policy, the €289 million increase is entirely higher fuel and operating cost, borne by all consumers through increased market prices. Under 80% hourly matching, about €160 million of the €222 million is the data centre's own investment in new wind and solar, while about €62 million is extra operating cost borne by all electricity consumers. **The rule puts most of the cost of new demand on the party that causes it**, and the investment it finances is clean capacity that stays in the Spanish system.

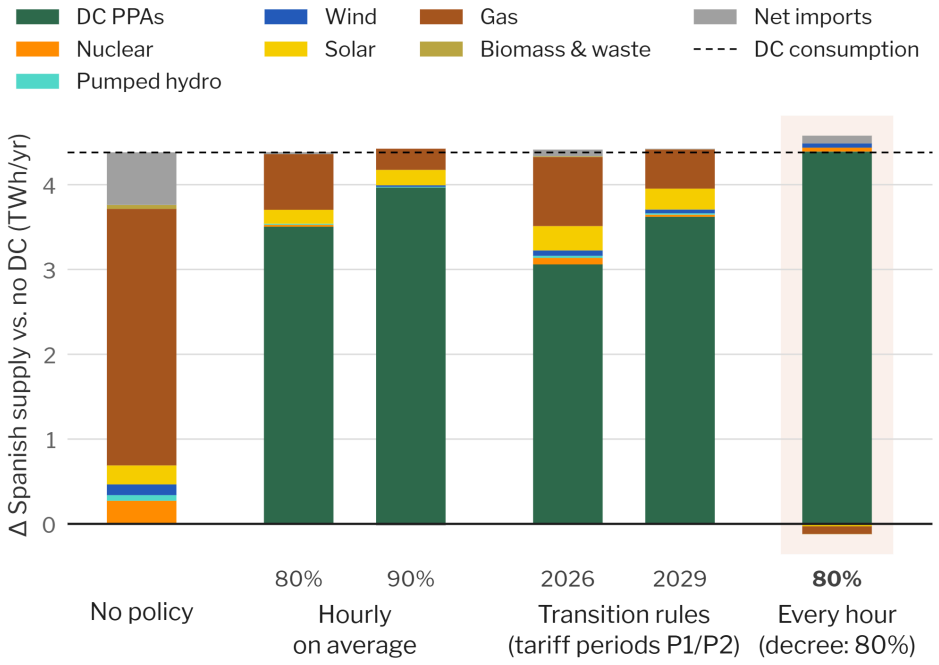
90% hourly matching goes further on every system metric, cutting emissions, gas burn and the price impact by more than the 80% design, at a higher but still moderate cost: the data centre pays 62 €/MWh instead of 54, and total system cost remains €32 million a year below no policy. Our modelling also shows that 80% hourly matching reduces emissions more and costs the system less than the first transition rule (P1). 90% hourly matching and the 2029 transition rule (P2) have a similar system cost (257.0 vs 257.2 M€) and data centre cost (62 vs 63 €/MWh). However, 90% hourly matching means a smaller emissions increase (0.08 vs 0.16 Mt) and passes less cost on to other consumers (€23 million vs €43 million). This is also an important finding for the feasibility of Spain's policy. As we describe further in section 2.5., designing the hourly matching rule as an average over the course of the year is much more feasible to implement than current rule and transition rules, which set a floor in each applicable hour.

Hourly matching on an annual average is the clear no-regret option in this analysis. It reduces emissions, protects other consumers from price increases and lowers total system cost compared to the no policy scenario, all at the same time. The cost per tonne of CO2 avoided (Figure 7) is **negative (−€80/t)**: society saves money while cutting emissions. Full summary tables of all the modelled results can be found in the GitHub repository.



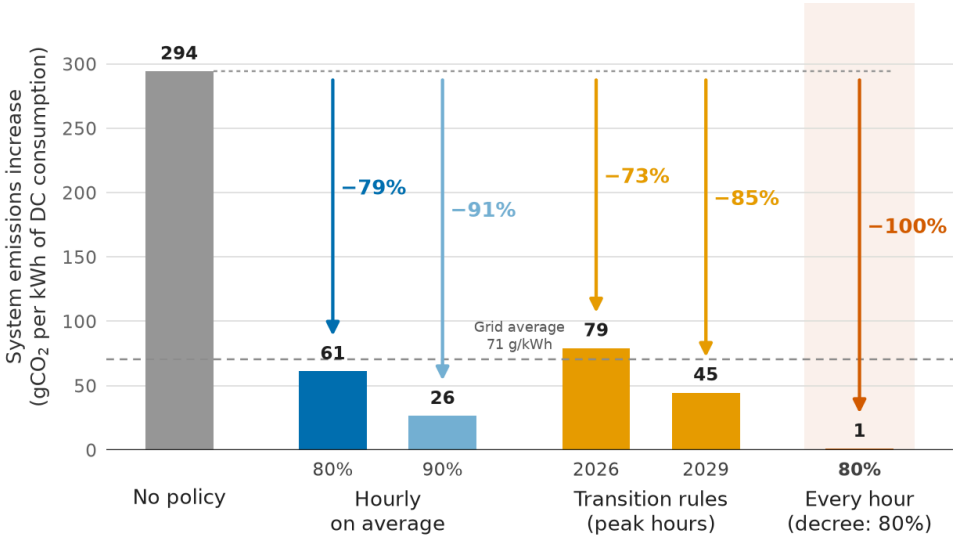
Change in the Spanish power system with a 500 MW data center in Aragon against a baseline without it: each bar carries the change and, in grey, the same change in percent of the baseline level. System cost: fuel, CO2 (EU ETS) and running costs of Spanish power plants and storage (light; imports excluded), then the data center's PPA and battery annuities on top (dark), ending at the total. CO2: fuel burnt in Spanish plants times its carbon content. Gas: fuel burnt in Spanish gas-fired power plants (CCGT, OCGT). Spot price: hourly nodal prices weighted by Spanish demand, the data center excluded. PPAs anywhere in mainland Spain. Transition rules: the revised draft's phase-in for data centers in the automatic load-reduction scheme, a floor in tariff periods P1 and P2 only, applied hour by hour as in Art. 9: 60% in P1 hours under the 2026 rules (to 2028), then 70% in P1 and 60% in P2 hours under the 2029 rules; all other hours are unconstrained (P1: 9–14 h and 18–22 h on weekdays in January, February, July and December; P2: 8–9, 14–18 and 22–24 h on those days, and 9–14 h and 18–22 h on weekdays in March and November local time, national holidays excluded).

Figure 1: Changes in system costs, emissions, gas burn and power prices



Change in Spanish electricity supply against no data center; dashed line: the data center's consumption. Surplus cannot be sold, so the data center's PPAs supply at most its own consumption (plus battery losses). PPAs anywhere in mainland Spain. Transition rules: the revised draft's phase-in for data centers in the automatic load-reduction scheme, a floor in tariff periods P1 and P2 only, applied hour by hour as in Art. 9: 60% in P1 hours under the 2026 rules (to 2028), then 70% in P1 and 60% in P2 hours under the 2029 rules; all other hours are unconstrained (P1: 9–14 h and 18–22 h on weekdays in January, February, July and December; P2: 8–9, 14–18 and 22–24 h on those days, and 9–14 h and 18–22 h on weekdays in March and November; local time, national holidays excluded).

Figure 2: Electricity mix serving a new 500 MW data centre



System emissions increase: the change in total power-system emissions (Spain, France, Portugal) caused by the data centre, divided by its consumption, against the same system without it. Arrows: change relative to no policy. Lower dashed line: average emissions of Spanish grid power over the hours a flat load consumes. Transition rules: the 26 Oct 2026 draft's optional phase-in, a floor only in peak tariff hours: 60% in P1 under the 2026 rules (to 2028), then 70% in P1 and 60% in P2 under the 2029 rules. 500 MW data centre in Aragon, Spain's 2025 fleet, weather year 2024, hourly resolution. Source: pypsalabs/spain-datacenter-decree.

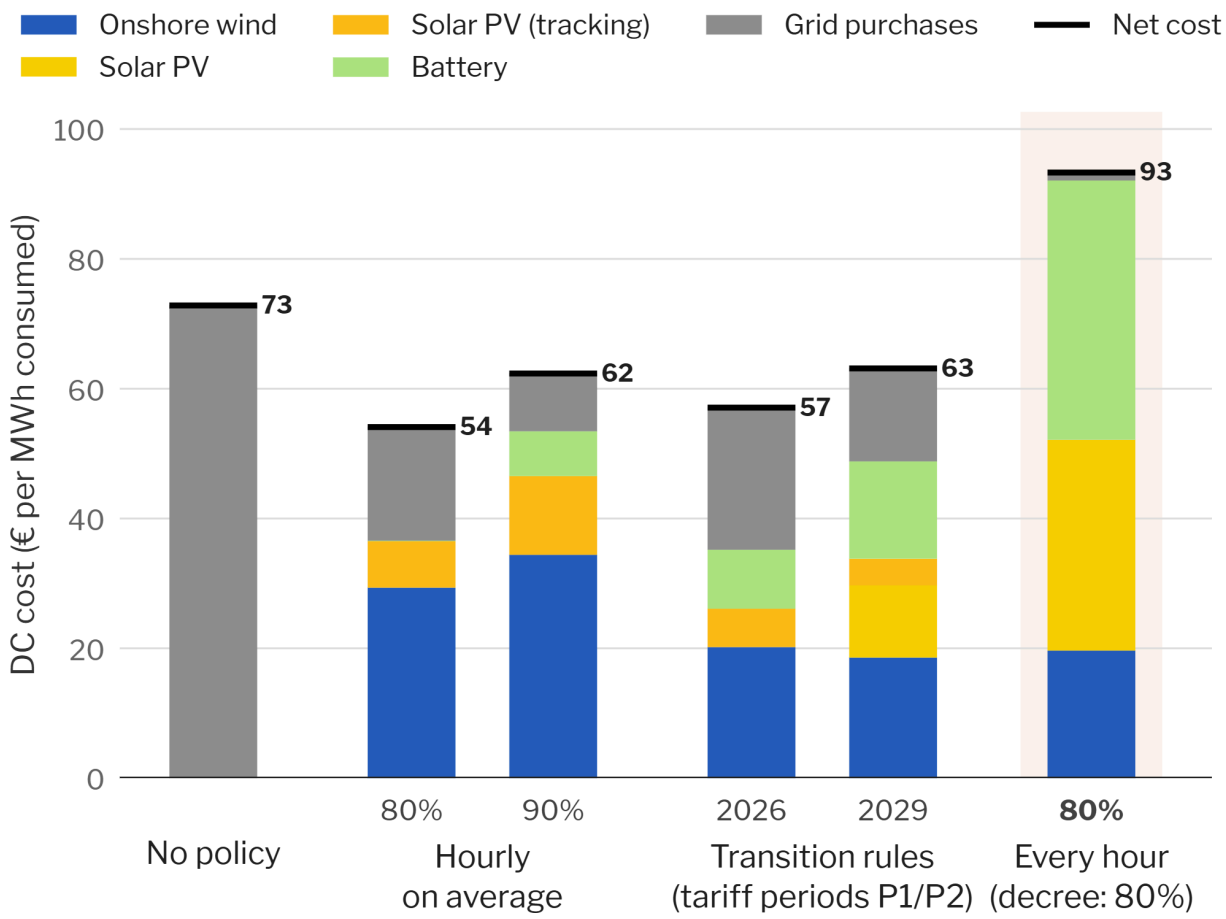
Figure 3: System-wide emissions increase of adding a 500 MW data centre

2.4 Finding (C): Hourly clean energy matching is cost effective

While the data centre industry in Spain has claimed that hourly matching is exorbitantly expensive, our modelling finds that, when designed appropriately (see Finding D), 80% and 90% hourly matching is cheaper for data centres than buying grid power.

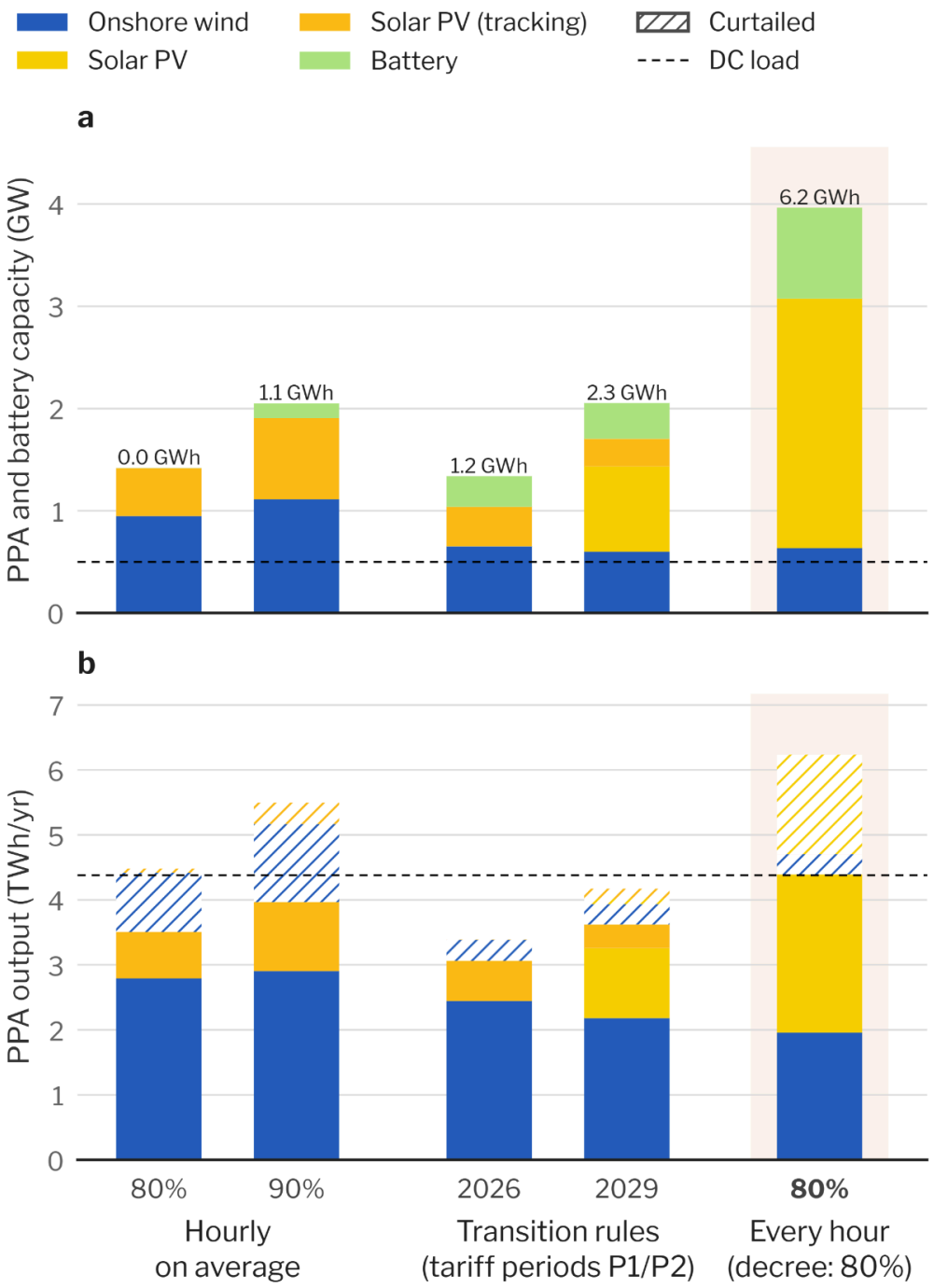
Figure 4 shows the cost of clean energy portfolios that meet different policy requirements, while Figure 5 shows the amount of capacity and generation that is built to meet each policy. To meet an 80% hourly matching target, a 500 MW data centre would build onshore wind (about 0.95 GW) plus tracking solar (about 0.5 GW). Wind blows at night and in winter, when the data centre would otherwise draw on gas. These PPAs cost less per MWh than buying grid power where gas sets the marginal price, even with about a fifth (22%) of their output curtailed because surplus is not sold in the model. The total cost of the portfolio is estimated at €54/MWh, 26% below the cost of grid power. 90% hourly matching can be achieved at a cost 14% below the grid power cost, through a combination of onshore wind, solar PV and battery storage.

According to WindEurope, Spain added 1.6 GW of onshore wind in 2025, up 33% from the 1.2 GW added a year earlier. This means that estimated wind procurement from a 500 MW data centre for the cost-optimal 80% hourly matching portfolio would be about 60% of the wind capacity Spain added in 2025. The significant expansion of wind power is widely viewed as necessary for Spain to meet its renewable energy and climate targets, yet deployment is currently constrained by permitting, grid connection, and supply chain delays. Nevertheless, WindEurope forecasts that 7.5 GW of wind power will be deployed in Spain in 2026–2030. PPAs from data centre operators could play a significant role in accelerating this wind energy deployment.



The data center's cost per MWh it consumes: PPA and battery annuities plus grid purchases (bold line: net cost). Surplus PPA output cannot be sold, so no revenue offsets it. PPAs anywhere in mainland Spain. Transition rules: the revised draft's phase-in for data centers in the automatic load-reduction scheme, a floor in tariff periods P1 and P2 only, applied hour by hour as in Art. 9: 60% in P1 hours under the 2026 rules (to 2028), then 70% in P1 and 60% in P2 hours under the 2029 rules; all other hours are unconstrained (P1: 9–14 h and 18–22 h on weekdays in January, February, July and December; P2: 8–9, 14–18 and 22–24 h on those days, and 9–14 h and 18–22 h on weekdays in March and November; local time, national holidays excluded).

Figure 4: Data centre procurement cost across six modelled scenarios



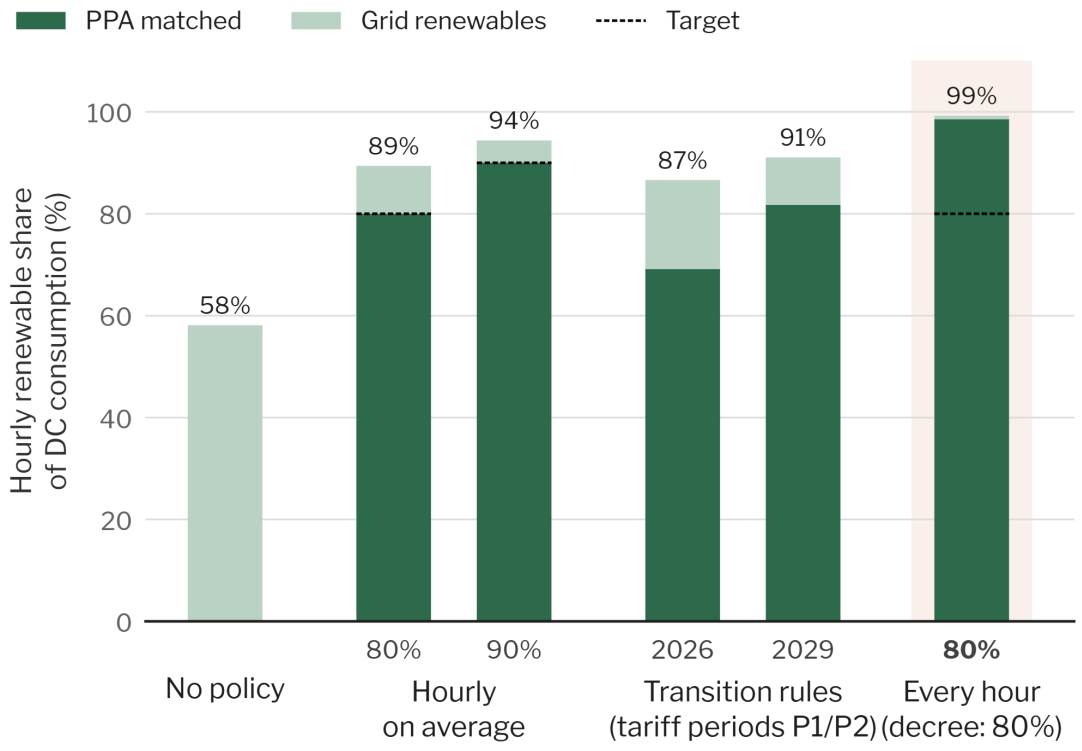
The data center's contracted assets (a) and their output (b); hatched: output curtailed, as surplus cannot be sold; dashed: the data center's load, as capacity (a) and annual consumption (b). PPAs anywhere in mainland Spain. Transition rules: the revised draft's phase-in for data centers in the automatic load-reduction scheme, a floor in tariff periods P1 and P2 only, applied hour by hour as in Art. 9: 60% in P1 hours under the 2026 rules (to 2028), then 70% in P1 and 60% in P2 hours under the 2029 rules; all other hours are unconstrained (P1: 9–14 h and 18–22 h on weekdays in January, February, July and December; P2: 8–9, 14–18 and 22–24 h on those days, and 9–14 h and 18–22 h on weekdays ir March and November; local time, national holidays excluded).

Figure 5: Clean energy capacity and generation added across the five modelled PPA scenarios

2.5 Finding (D): Design matters. A floor in every hour is more costly than necessary and challenging to implement

The draft decree's requirement of 80% hourly matching in **every** hour of data centre consumption nearly eliminates any negative consequence of data centre buildout on emissions and electricity prices (Figure 1). However, it does so at a significant cost to both data centres and the electricity system. This is because, to achieve the 80% hourly minimum, the clean energy portfolio must be sized for the hardest hours of the year, such as the winter lulls when wind and sun are both low.

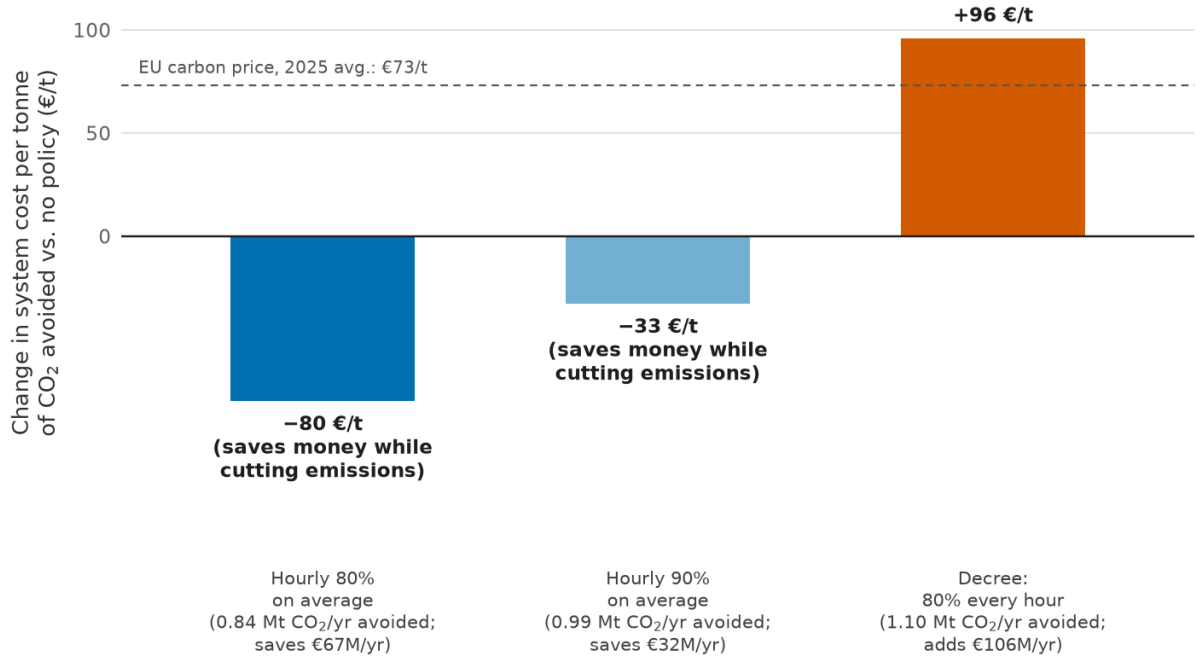
As a result, the policy forces data centres to significantly oversize solar, wind and battery storage resources. In our model, meeting a strict 80% minimum in every hour results in 99% hourly matching on average over the year, as seen in Figure 6. To achieve this, a 500 MW data centre would need to build 3.1 GW of new clean energy capacity and a 0.9 GW / 6.2 GWh battery. Its contracted output would total 6.2 TWh, 41% more than its consumption.



Share of the data center's consumption covered by renewables in the same hour: by its own PPAs and battery (dark), or by the renewable share of its grid purchases (light; import-traced, nuclear excluded). PPAs anywhere in mainland Spain. Transition rules: the revised draft's phase-in for data centers in the automatic load-reduction scheme, a floor in tariff periods P1 and P2 only, applied hour by hour as in Art. 9: 60% in P1 hours under the 2026 rules (to 2028), then 70% in P1 and 60% in P2 hours under the 2029 rules; all other hours are unconstrained (P1: 9–14 h and 18–22 h on weekdays in January, February, July and December; P2: 8–9, 14–18 and 22–24 h on those days, and 9–14 h and 18–22 h on weekdays in March and November; local time, national holidays excluded).

Figure 6: Hourly renewable energy matching share across all modelled scenarios.

We calculate that this would cost 93 €/MWh, 20 €/MWh more than buying from the grid, and 39 €/MWh more than under the annual-average design. It would increase system costs by €395 million per year, which is €106 million more than having no policy at all, and €173 million more than the annual-average design. As shown in Figure 7 below, the 80% and 90% hourly average matching cases both reduce system costs while also reducing emissions, whereas the 80% hourly minimum would cost the system €96 per tonne of CO2 avoided.



Each bar compares a policy design with no policy: the change in Spanish system cost divided by the CO2 emissions avoided. Negative: the design lowers system cost and cuts emissions. 500 MW data centre in Aragon, Spain's 2025 fleet, weather year 2024, hourly resolution. Source: pypsalabs/spain-datacenter-decree.

Figure 7: Change in system cost per ton of CO2 avoided by policy scenario

Our analysis suggests that, instead of designing the rule as an 80% floor for each hour, the Spanish government could achieve most of the benefits at a much lower cost by calculating hourly matching as an average over the course of a year. Figure 8 shows how this works. The current policy, shown on the left, requires the data centre to significantly overbuild clean energy to ensure that every hour is matched at 80%, or else pay a non-compliance penalty. The average measurement on the right shows that if a data centre matches 60% with renewables in one hour, it can compensate by matching 100% in another. This allows the data centre to contract a smaller amount of capacity that is more feasible to build while still significantly reducing emissions.

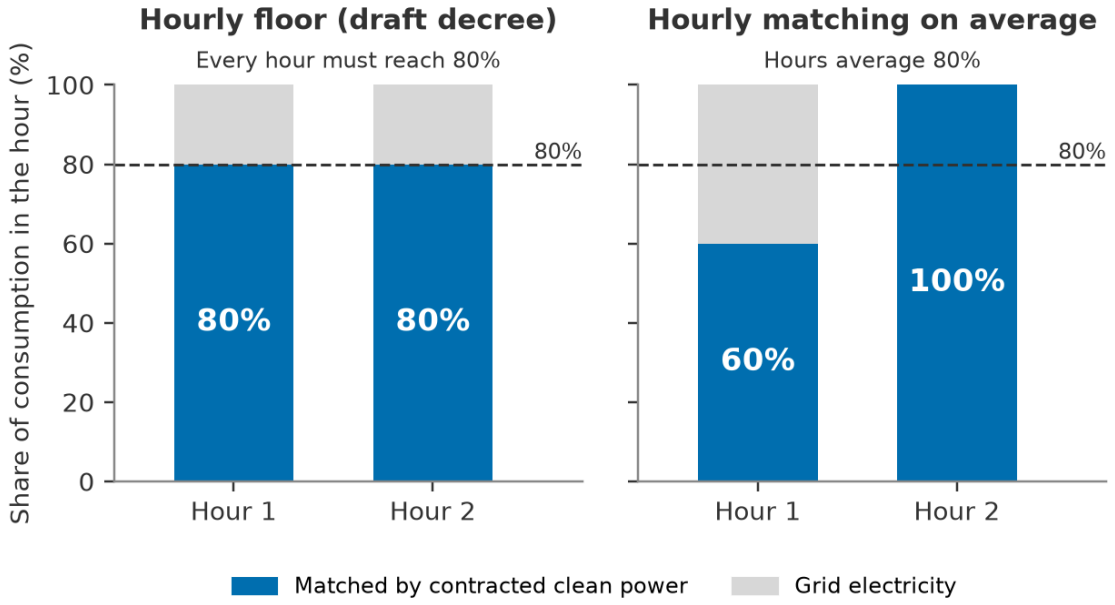
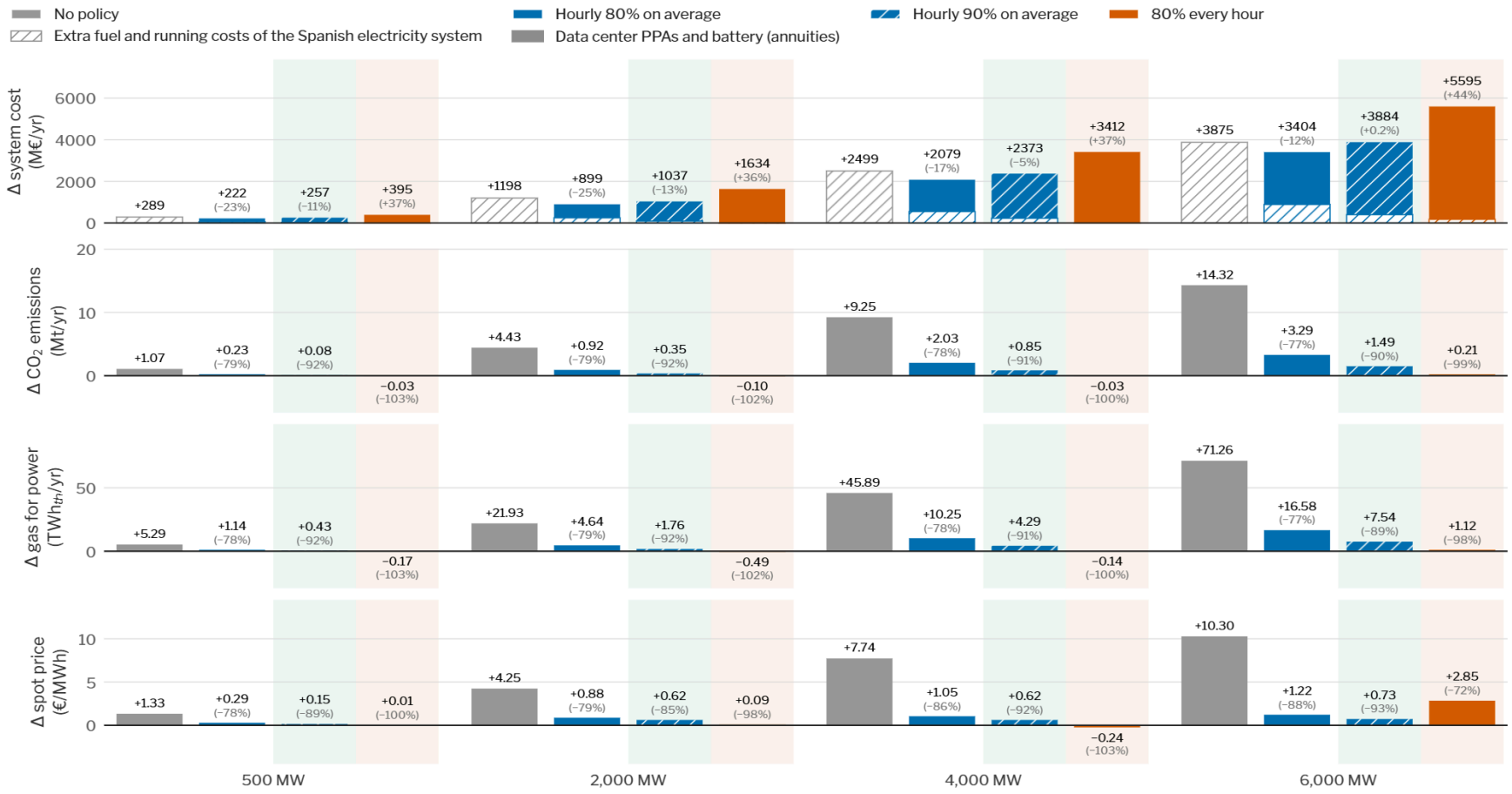


Illustration. Both designs cover 80% of consumption with contracted clean power over the two hours. The floor allows no hour below 80%; the average lets a windy or sunny hour make up for a weaker one.

Figure 8: Illustration of an hourly floor versus hourly matching on an annual average

2.6 Finding (E): Impacts grow with the data centre buildout

Data centres already hold 6.3 GW of granted grid access in Spain, so a single 500 MW campus is only a small part of what could be built. We therefore also modelled buildouts of 2,000, 4,000 and 6,000 MW, each added to today's power system as one flat load in Aragón. Figure 9 compares no policy with each matching design at each size



Change in the Spanish power system with a data center of 500 to 6,000 MW in Aragon against a baseline without it, by size and procurement policy: each bar carries the change and, in grey, its difference to the no-policy case of the same size. System cost: fuel, CO2 (EU ETS) and running costs of the Spanish electricity system (hatched; imports excluded), then the data center's PPA and battery annuities on top (solid), ending at the total. CO2: fuel burnt in Spanish plants times its carbon content. Gas: fuel burnt in Spanish gas-fired power plants (CCGT, OCGT). Spot price: hourly nodal prices weighted by Spanish demand. PPAs anywhere in mainland Spain.

Figure 9: Change in emissions, power prices and system cost by data centre buildout size

Three takeaways stand out:

- **Without a policy, the impacts grow with the buildout.** At 6,000 MW, Spanish power-sector emissions would rise by about 80% and the spot price by about 14%, as existing gas plants run more and set the price more often.
- **Hourly matching keeps most of that impact off the system at every size.** It avoids around four-fifths of the emissions increase, and an even larger share of the price increase as the buildout grows.
- **It stays cheaper than doing nothing.** Total system cost is lower than with no policy at every size, by up to €470 million a year at 6,000 MW. Data centres also continue to pay less than they would for grid power, although their cost per MWh rises with scale as larger buildouts need less windy sites and more storage.

The procurement needs grow too. Meeting 80% hourly matching on an annual average for a 6,000 MW buildout means contracting about 22 GW of new wind and solar, including about 10.6 GW of onshore wind. That is roughly six to seven years of onshore wind additions at Spain's 2025 rate. At this scale, the pace of renewable deployment, not the matching rule itself, becomes the binding constraint, which is why the requirement must be backed by faster renewable deployment (see Recommendation 7).

2.7 Study Limitations

The results of this study illustrate likely outcomes from different renewable energy matching policy designs for Spain's data centre buildout, but there are a number of caveats:

- **One weather year.** 2024 was a wet, high-renewable year in Iberia. Drier or less windy years would make every hour harder to cover, which would most likely raise the cost of the every-hour rule more than the others.
- **No surplus sales.** In the presented results, we assume that the data centre cannot sell surplus PPA output to the grid. It can store it in a battery it pays for, and the model builds that battery whenever storing is cheaper than contracting more wind or solar. Only output it can neither use nor store at reasonable cost is curtailed. In practice, that remainder would normally be sold into the wholesale market, earning some revenue and displacing other generation. This is a conservative assumption, as including surplus sales would reduce the cost of hourly matching even further than is presented in the analysis; however, the magnitude of the cost differential between 80% hourly matching on average and a minimum 80% requirement per hour would likely be similar.
- **Price level and gas price.** The data centre's own demand impacts the price it pays: in the no-policy case it buys all its power from the grid, and gas sets the price in more hours because of it. Modelled wholesale prices are somewhat higher than actual: the

model's average Spanish spot price is 71.9 €/MWh, above the 65.3 €/MWh observed in 2025. The data centre's grid cost (73 €/MWh) and the savings from switching to PPAs may therefore be somewhat overstated. The comparison between the matching designs is much less affected, because they all rely mainly on PPAs rather than grid purchases. Today's gas market pulls the other way. The model runs on 2025 fuel prices, with gas at 36 €/MWh. In late October 2026 the European benchmark TTF touched 100 €/MWh for the first time since 2022. At that price, the extra 5.3 TWh of gas burned in the no-policy case would cost roughly €340 million a year, more than doubling its system-cost impact, while the PPA-based designs are much less exposed. The gas-price exposure the rule removes is therefore much larger today than our 2025 numbers show.

- **Not modelled.** The draft's surcharge regulation tolerates a share of failing hours, so the decree as proposed is somewhat softer than our every hour case. The case in our model is an upper bound on its cost. Network tariffs are outside the model, so we cannot price the surcharges themselves. Additionally, the transition cases model only the P1/P2 floors. Article 8's 80% annual volume is not added, because the revised draft lets solar of any age count towards it if the plant had no PPA when the decree enters into force. The volume can be filled with existing solar that changes nothing in the system, so requiring 80% of new build would overstate the rule. In any case, the floors alone bring contracted output close to or above the 80% volume: 77% of consumption under the 2026 rule and 95% under the 2029 rule.
- **Procurement costs.** Procurement costs are based on the levelized cost of the renewable energy technologies that are deployed, and do not necessarily correspond to the market price for power purchase agreements (PPAs) in Spain. For reference, LevelTen's P25 PPA offer prices in Spain during 2025 ranged from about €32.50 to €37/MWh for solar and €53 to €57/MWh for wind (LevelTen PPA Price Index, as reported by Energías Renovables for Q1 and by AEE for Q3 and Q4). These are developer offer prices, not signed contract prices.

3. Recommendations for policymakers

1. Keep the principle: new data centres should bring new clean supply, matched in time. The analysis shows that doing nothing is the most carbon-intensive option and, in this model, not the cheapest. The draft's additionality and hourly correlation requirements are the right foundation.

2. Keep the hourly target, but measure it as an annual average rather than a floor in every hour. Compliance should be measured as the sum over the year of matched energy, counting in each hour no more than the data centre's consumption in that hour, divided by annual consumption: an hourly matching score of at least 80%. This keeps the time-matching discipline that drives hybrid renewable energy procurement. It avoids sizing every portfolio for the worst winter hours, which makes the rule more expensive for the system.

3. Keep the transition period, but replace the P1/P2 floors with 80% hourly matching averaged over a year. Our analysis shows that 80% hourly matching on average is cheaper for the system and reduces emissions and electricity prices more than the P1 transition rule which targets 9% of hours. 80% average matching is also more intuitive and easier for data centres to implement, with some data centre operators already pursuing this approach.

4. Use the draft's five-year transition to reach 90% average hourly matching. Our analysis shows that 90% hourly matching averaged over the year is cheaper than the no policy scenario, can be achieved at a procurement cost below grid power, and significantly reduces system emissions and electricity prices. This can be reached by the end of the draft's five-year transition.

5. Verify compliance with hourly data. In the absence of time-stamped Guarantees of Origin issued by the national issuing body, the system operator can verify compliance, as the draft already provides, using meter data from the contracted plants and the data centre, to ensure that there is no double counting of resources.

6. Use the review clause to raise ambition over time. The draft already asks the CNMC, Red Eléctrica and MITECO to evaluate the thresholds every two years (fifth additional provision). Base that evaluation on open, reproducible models like the one behind this report. Our results indicate that 90% hourly matching on average is achievable at close to the cost of grid power (including the extra gas burn and price rise the data centre cluster itself causes), so the first review should confirm the path to 90% in Recommendation 4.

7. Back the requirement with an enabling environment for new clean supply. The rule works by adding new wind, solar and storage to the system, so it should be paired with measures that get those projects built on time: efficient permitting and grid connection for the projects data centres contract, and full use of existing grid connections. Delays would increase gas reliance, hurting data centres, consumers and the government alike.

FAQ

About the model

The model is based on one historical year, 2024, giving perfect foresight. Won't real buyers need a safety margin?

Yes. A buyer aiming for 80% on average would likely contract a buffer. Our 90% case shows what that margin costs: the data centre still pays 62 €/MWh, 14% below grid power, and avoids about 90% of the no-policy emissions increase. The draft's graduated surcharges for non-compliance also provide some flexibility around the 80% target.

Aren't the PPA prices cost-based rather than market-based?

Yes. They are annualised technology costs, without developer margin, risk premium or balancing costs. This is the standard approach for such modelling, as robust PPA price data is incomplete and largely proprietary. Either way, it does not change the case made here: margins apply to every design and would widen the cost gap between the every-hour rule and the annual average.

About the policy

Wouldn't annual matching address data centre impacts?

No. Annual matching rewards the cheapest MWh regardless of when it is produced, and in Spain's PPA market that is midday solar, often contracted by buyers who claim the green attributes elsewhere in the EU. That deepens the midday surplus instead of delivering clean electricity to cover night-time demand. We modelled results associated with annual matching, which can be found in the GitHub repository.

Isn't switching to an annual average just lowering the bar?

It strikes a sweet spot. The 80% annual average removes about 80% of the extra emissions and price impact, and costs less than having no policy. Requiring 80% in every hour removes most of the rest, but the every-hour rule costs the system €173 million a year more than the 80% average (section 2.5) and avoids 0.26 Mt more CO2 (Figure 1), so about €660 per tonne for that last step, roughly nine times the 2025 average EU carbon price. Ambition can rise over time: 90% on average removes about 92% of the emissions increase at close to the cost of grid power.

Does additionality make sense when solar is already curtailed at midday?

It is a fair concern, and hourly matching is the better answer to it. Because it rewards clean power at night and in winter, the 80% average portfolio includes a significant amount of wind and less midday solar. We also see a case for flexibility in surplus hours: consumption when

prices are zero or negative could count as matched, which would reward data centres for shifting load into those hours. Annual matching would make the problem worse. Spain's PPA market is largely solar, contracted for annual volumes (often by buyers who claim the green attributes in other EU markets) rather than for when the system needs power, which deepens the midday surplus.

Spanish energy suppliers already have renewable energy commitments. Doesn't this help meet data centre demand?

Mostly not. Supplier green tariffs and corporate renewable claims in Spain, as elsewhere in Europe, are largely backed by Guarantees of Origin from existing wind, solar and hydro plants. Buying these certificates moves the green label of power that is already being generated, and already counted in the grid mix, from one customer to another. It does not add new clean supply. If a new data centre's demand is covered this way, existing gas plants still run more to serve it: that is the 294 g CO2/kWh system emissions increase we find in the no policy case.

The practice is widespread. A 2025 study for the European Commission, based on the first round of data centre reporting under the Energy Efficiency Directive, found that over 70% of reporting data centres claimed 100% renewable electricity on an annual basis, and that around 70% of that renewable electricity was backed by Guarantees of Origin rather than contracts for new supply such as PPAs (European Commission, DG ENER, 2025). The study notes that Guarantees of Origin can come from long-depreciated plants and do not necessarily lead to new low-carbon investment, and recommends reporting the share of hourly-matched renewables in future. Additionality and hourly matching are what turn a renewable claim into new clean electricity at the hours a data centre actually consumes.

Does hourly matching reduce curtailment?

Yes, for two reasons. First, hourly matching gives new batteries a contracted revenue stream to charge with electricity that would otherwise be curtailed and discharge it when renewable output is low, without relying on day-ahead price spreads that shrink as more storage is built. Second, it leaves up to 10-20% of consumption to be covered by grid power, which in surplus hours comes from cheap renewable output that would otherwise be curtailed.

About the system

Can Spain build this much wind?

Each 500 MW data centre needs about 0.95 GW of new wind under the 80% average. According to WindEurope, Spain added about 1.6 GW of wind in 2025, 33% more than the amount deployed in 2024. Long-term data centre contracts can help finance that buildout, but they do not remove the real bottlenecks: permitting, grid connection, local acceptance and supply chains. At multi-gigawatt scale, these, rather than the matching rule, become the binding constraint.

How does hourly matching affect demand for solar and storage?

At 80% on average, wind leads, making up about two-thirds of contracted capacity, because it

produces at night and in winter when a data centre most needs supply. Solar is in every portfolio, though, and its share grows with higher targets and larger buildouts, increasingly paired with storage. At 90%, a 500 MW data centre contracts 0.8 GW of solar and 1.1 GWh of batteries. For a 6 GW buildout at 80% hourly annual average, about half the contracted capacity is solar, alongside about 12 GWh of storage.

Isn't hourly matching impossible without hourly certificates?

No. The data it needs already exists. European power markets now settle in 15-minute intervals, and under Article 9.3 the system operator already receives metering data for both the data centre and its contracted plants and checks compliance monthly. A growing number of companies already track and report hourly matching this way. Time-stamped Guarantees of Origin would make tracking easier, but they are not a precondition.

Annex

A1. Model validation

See the validation section of the github repository for a detailed description of how the model was validated against reported Spanish electricity system data.

A2. Glossary

- **Additionality.** The requirement that clean electricity comes from new installations that would not otherwise have been built.
- **Annual matching.** Buying renewable energy equal to annual consumption, regardless of when it is produced.
- **Hourly matching (24/7 CFE).** Counting clean energy only in the hour it is produced and consumed. The **hourly matching score** is the share of consumption matched hour by hour, summed over the year.
- **80% every hour (floor).** At least 80% matched in each individual hour, as in the draft decree.
- **80% (or 90%) on average.** An hourly matching score of at least 80% (or 90%) across the year.
- **Attributional intensity.** Emissions assigned to consumption using the average emission factor of grid supply in each hour.
- **Consequential intensity (system emissions increase).** The actual change in total system emissions caused by the new consumption, per kWh consumed.
- **Curtailment.** Renewable output that is available but not used.
- **Spanish System Cost:** The fuel, CO2 (EU ETS) and running costs of the Spanish electricity system.

A3. Other Cases Run

Beyond the cases in the main text, the study ran a wider set of scenarios. Full results are in results/scenarios.csv in the GitHub repository. For a 500 MW data centre:

- **Annual matching.** The data centre contracts enough renewable output over the year to cover 80% of its consumption, with no regard to timing. Much of that output arrives at midday, when the data centre's demand is already covered, so gas plants still fill the nights. The emissions increase is about half as large again as under hourly matching, and the price impact is higher.

- **Grid credit.** Hourly matching in which the renewable share of the grid power the data centre buys also counts towards the target.
- **Local procurement.** Hourly matching with contracts limited to the data centre's own region, Aragón, instead of anywhere in mainland Spain. Emissions are cut almost as much, but without access to Spain's best wind sites the portfolio shifts to solar and batteries, and the data centre's cost rises from 54 to 84 €/MWh.
- **90% targets and larger buildouts.** Every design was also run with a 90% target, including 90% in every hour, and every case for buildouts of 500, 2,000, 4,000 and 6,000 MW.

A4. Reproducibility

Everything behind this report is public under the MIT licence at github.com/pypsalabs/spain-datacenter-decree

- **What is there.** The model configuration, the reproducible scientific workflow, the full results table (results/scenarios.csv: all policies, 500 to 6,000 MW, 80% and 90% targets, hourly resolution), the summary figures, and the validation report against Red Eléctrica's 2024 data.
- **How it is built.** PyPSA-Eur, an open European power-system model, pinned to the latest release. All study design choices sit in a small overlay on top of it. Inputs are open data: ERA5 and SARAH-3 weather data, open technology costs, published market prices and fleet statistics, each cited in the repository.
- **How to reproduce it.** Two commands rebuild the model, solve every scenario and redraw the figures. The open-source solver HiGHS reproduces the results without a licence; a full-year hourly scenario needs about 10 GB of memory.
- **Background method.** Riepin, I. & Brown, T. (2024), *On the means, costs, and system-level impacts of 24/7 carbon-free energy procurement*, Energy Strategy Reviews, doi:10.1016/j.esr.2024.101488.

Declaration of Interests

Killian Daly is Executive Director of EnergyTag, an independent, grant-funded clean energy non-profit that works on round-the-clock clean power markets and does not sell services, take sponsorships or operate a membership model. Iegor Riepin is a co-founder of PyPSA Labs gGmbH, a non-profit company, who carried out the underlying modelling without dedicated funding, grant or direction for it, from any government, company or interest group. Neither organisation has any commercial interest in the outcome of this policy.

Author bios

Killian Daly: Executive Director of EnergyTag, a non-profit organisation driving decarbonization in the power sector by advancing electricity markets and carbon accounting globally. Killian has advised institutions, including the International Energy Agency, US Federal Government, European Commission, on clean energy markets and has been featured in leading media publications such as the Financial Times and Bloomberg. Killian was named a 2026 World Economic Forum Young Global Leader in recognition of his clean energy work. Before leading EnergyTag, Killian managed global energy strategy at Air Liquide, one of the world's largest industrial companies. He holds a Master's Engineering degree in Energy Technologies from the University of Cambridge.

Iegor Riepin: Co-founder of PyPSA Labs, a non-profit advancing climate protection and energy systems research through development, co-maintenance, support and training for the open-source PyPSA software ecosystem. His work focuses on mathematical models in the energy field: their applications to real-world problems, their limitations, and their impact on decision-making. He holds a PhD in energy economics from Brandenburg University of Technology.