

Spanish wholesale electricity price dynamics

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K4K services

- Broad range of services to financiers, utilities, IPPs and governmental agencies.
- Team background in energy consulting and strategic advisory.
- Regulatory and market due diligence reports that are relied upon by lenders.
- Supported successful completion of 72GW with a transaction value of US\$44 billion, including 15GW in Spain.
- Recent Iberian track record developed as market modelling director of EKON Strategy Consulting during 2015-2022. EKON now a registered brand of K4K.

Sample Service Range



Spanish Electricity Price Dynamics

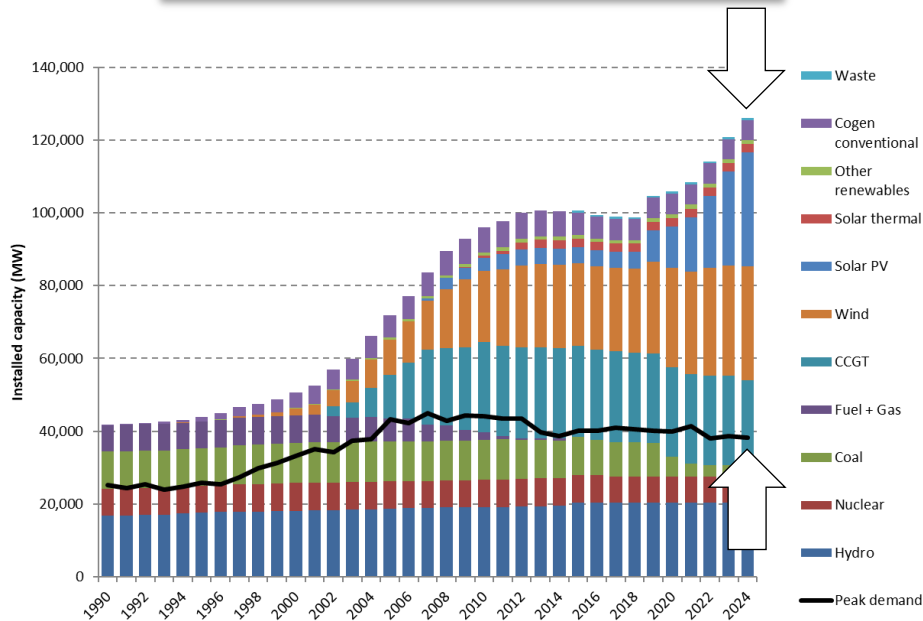


- Background
- Key concepts
- Review of recent events
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- Modelling results
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- Final comments

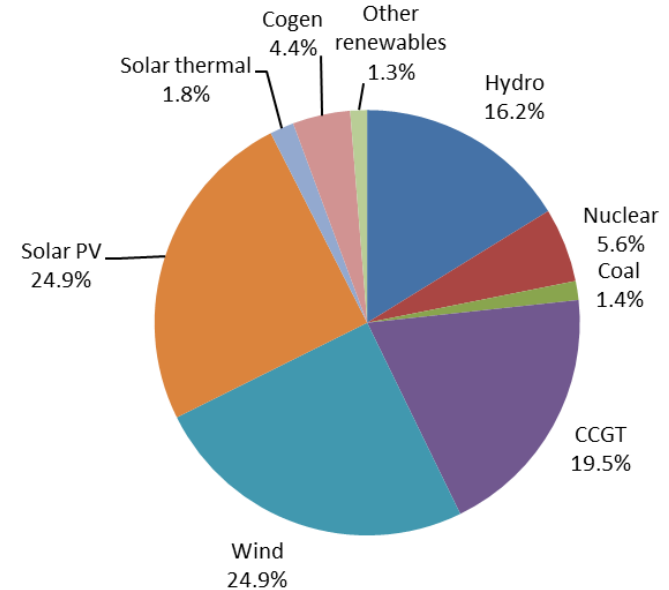
Historical capacity mix

- We are not building renewables cause the lights are about to go out...

Evolution of installed capacity

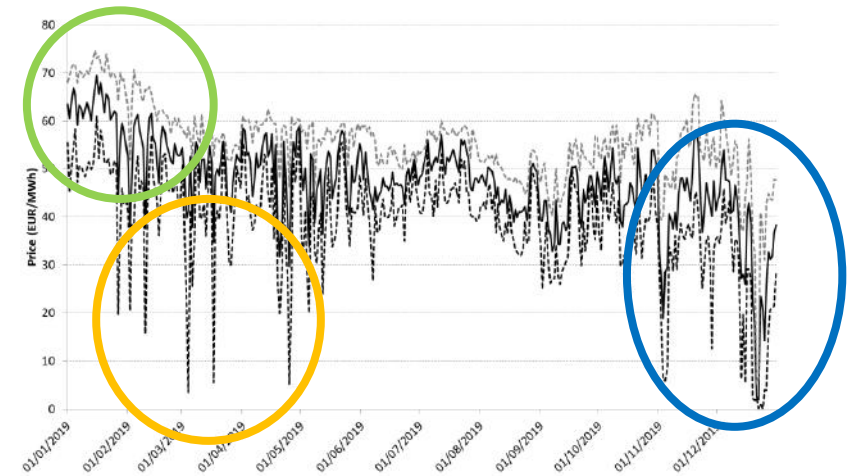
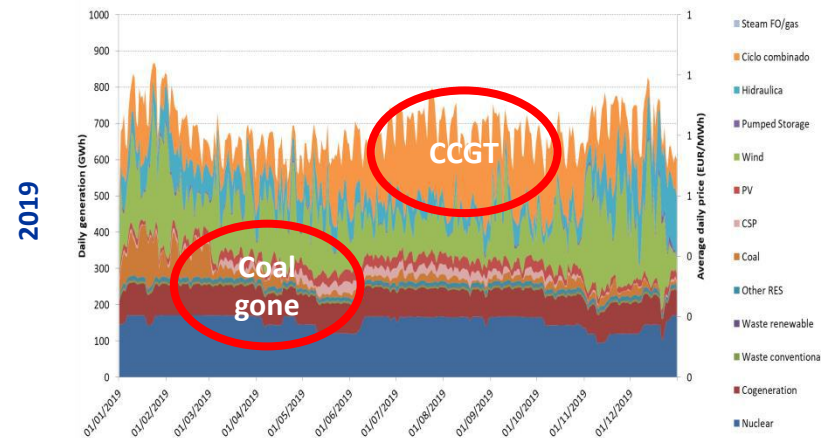
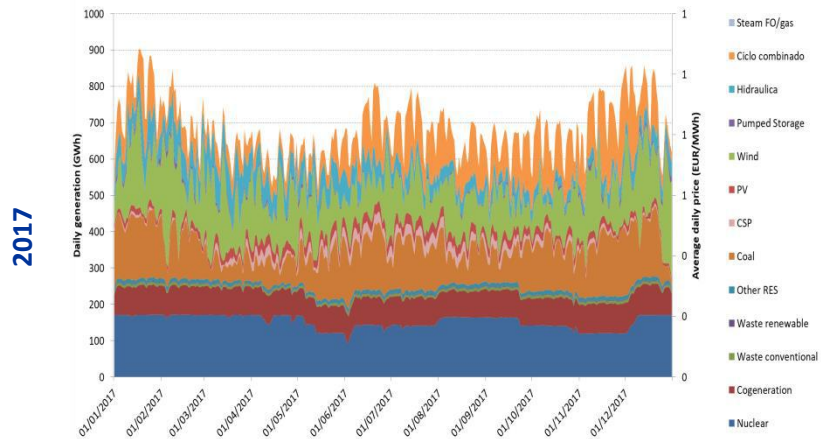


Capacity mix (end 2024)



What to make of market outcomes?

- Hourly data for 2017 and 2019 shows volatility of market prices and generation.



Source: REE ESIOS.

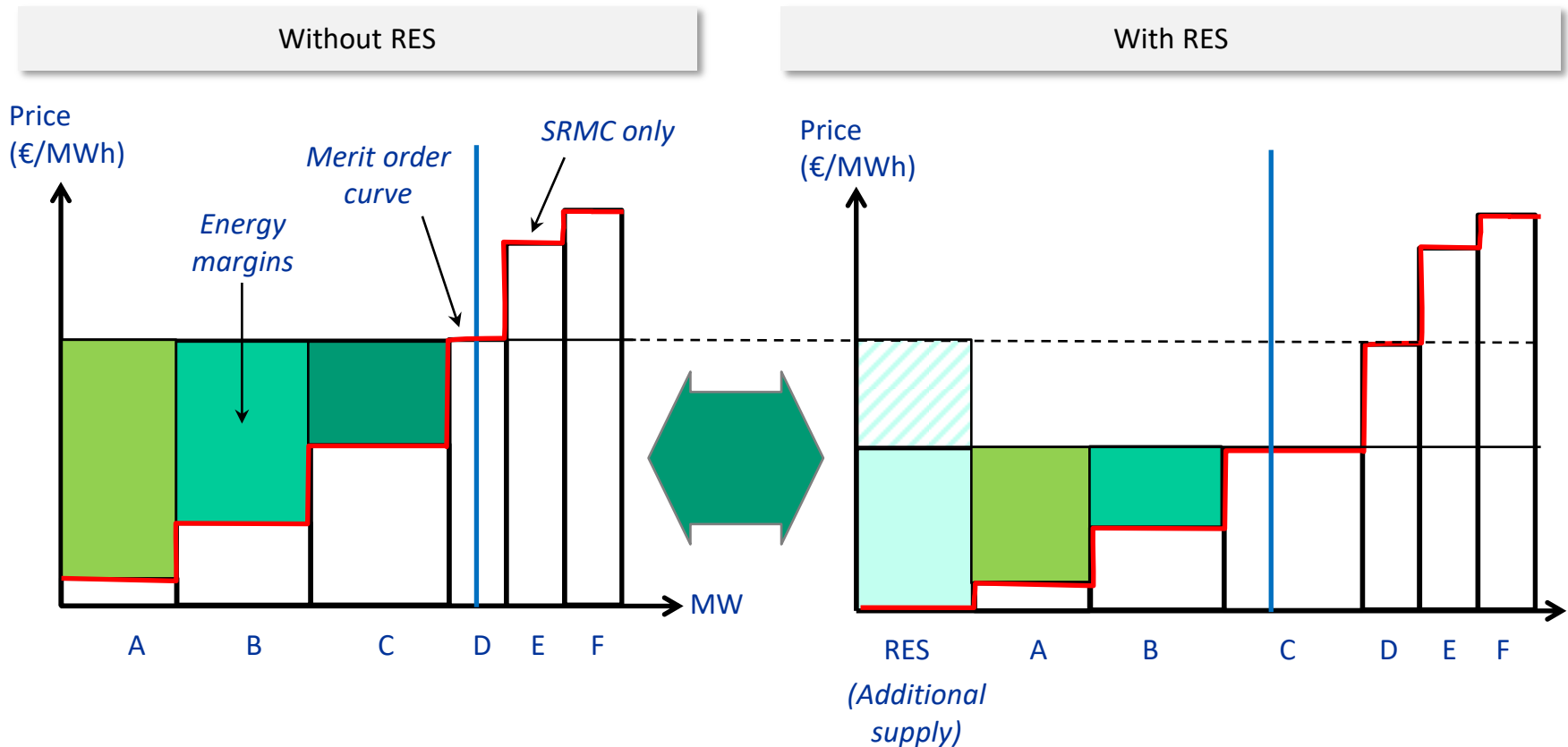
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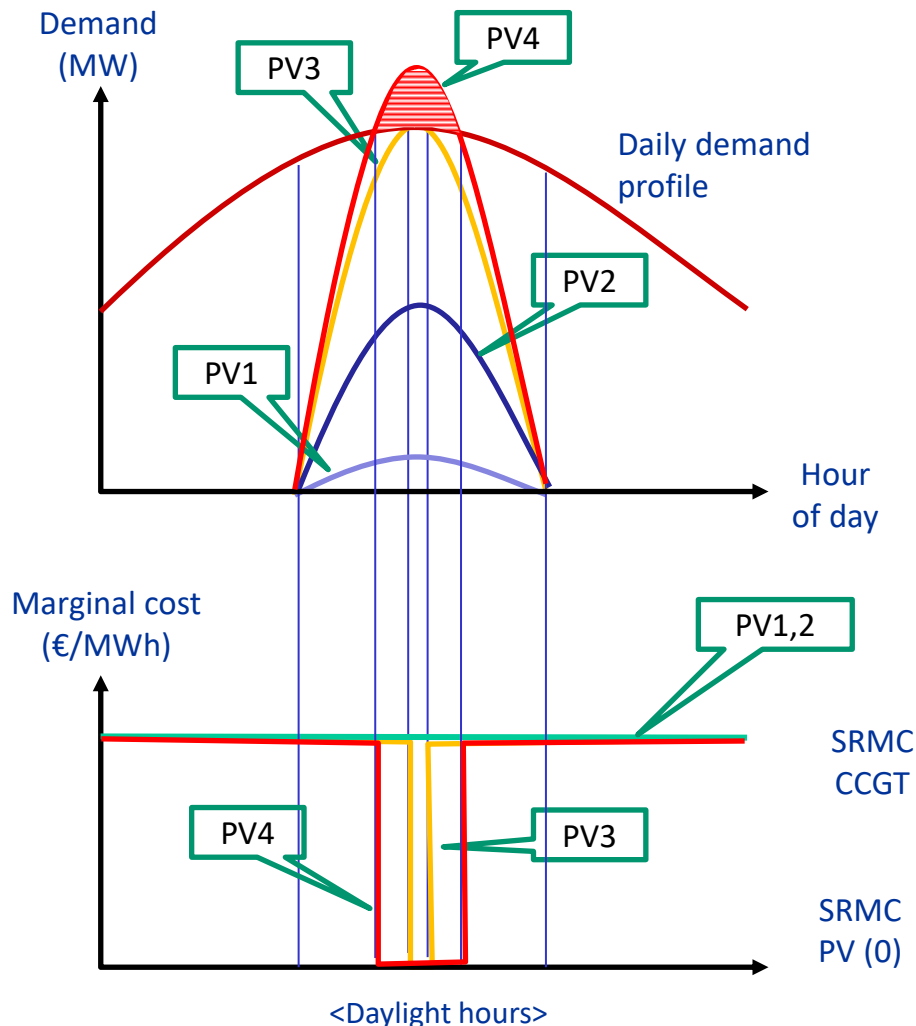
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The chicken (duck?) and egg problem...

- Market participants make an assessment of profits from the energy market. Renewables energy sources ("RES") are price takers but will still affect market outcomes thereby reducing their remuneration the more they produce.



PV saturation when realised price of PV = LCOE



- Consider simple 24-hour set-up with gas-fired CCGT. As you add PV capacity (PV1, PV2) prices will still be set by CCGT. After a point, the prices drop.
- After market reaches saturation point, there is no commercial incentive to build more PV. (Note that this point has no “missing money” problem, which happens when deployment is pushed beyond this limit .)
- Note that excess generation forms part of the market equilibrium!

Source: K4K.

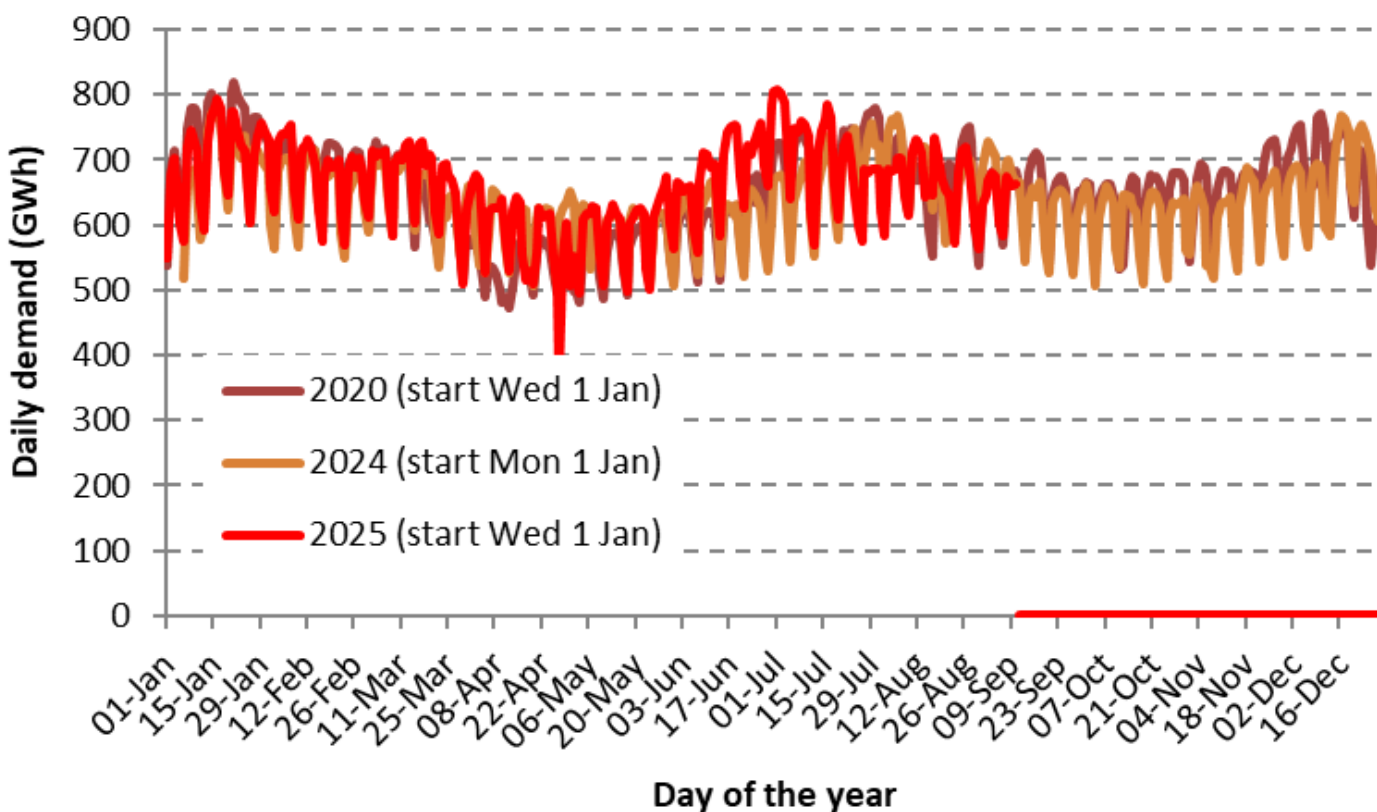
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Evolution of demand in 2025

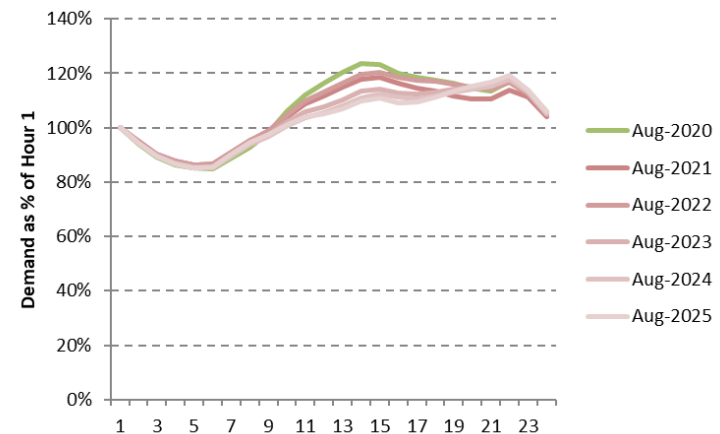
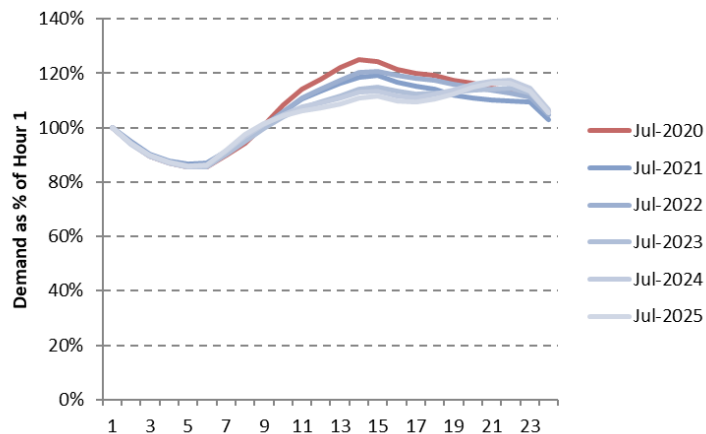
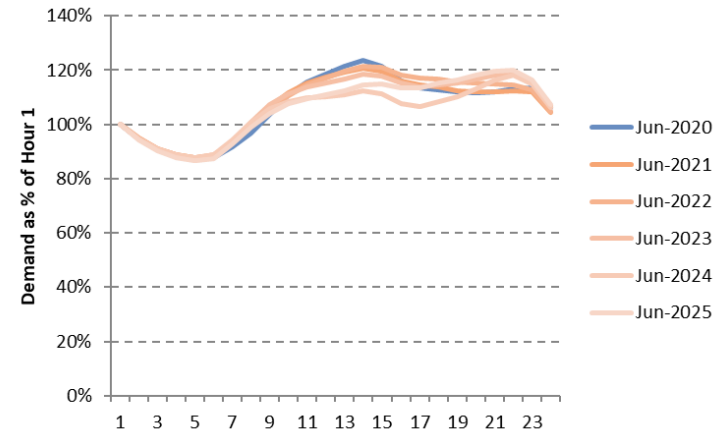
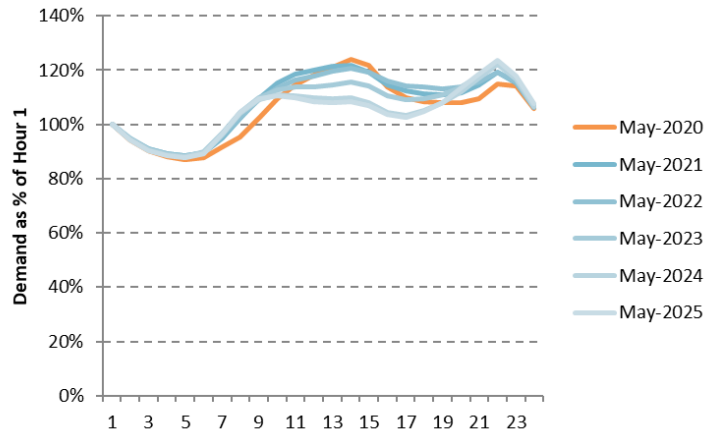
- Below shows REE daily demand (synched by weekday) for mainland Spain in 2020, 2024 and 2025 until 7 September. On cumulative basis, mainland demand in 2024 was still 1.37% below that in 2020 even if 2024 was 1.58% higher than in 2023. That said, demand in the first 253 days of 2025 has been 2.48% higher than the same period in 2024.



Source: REE and K4K calcs.

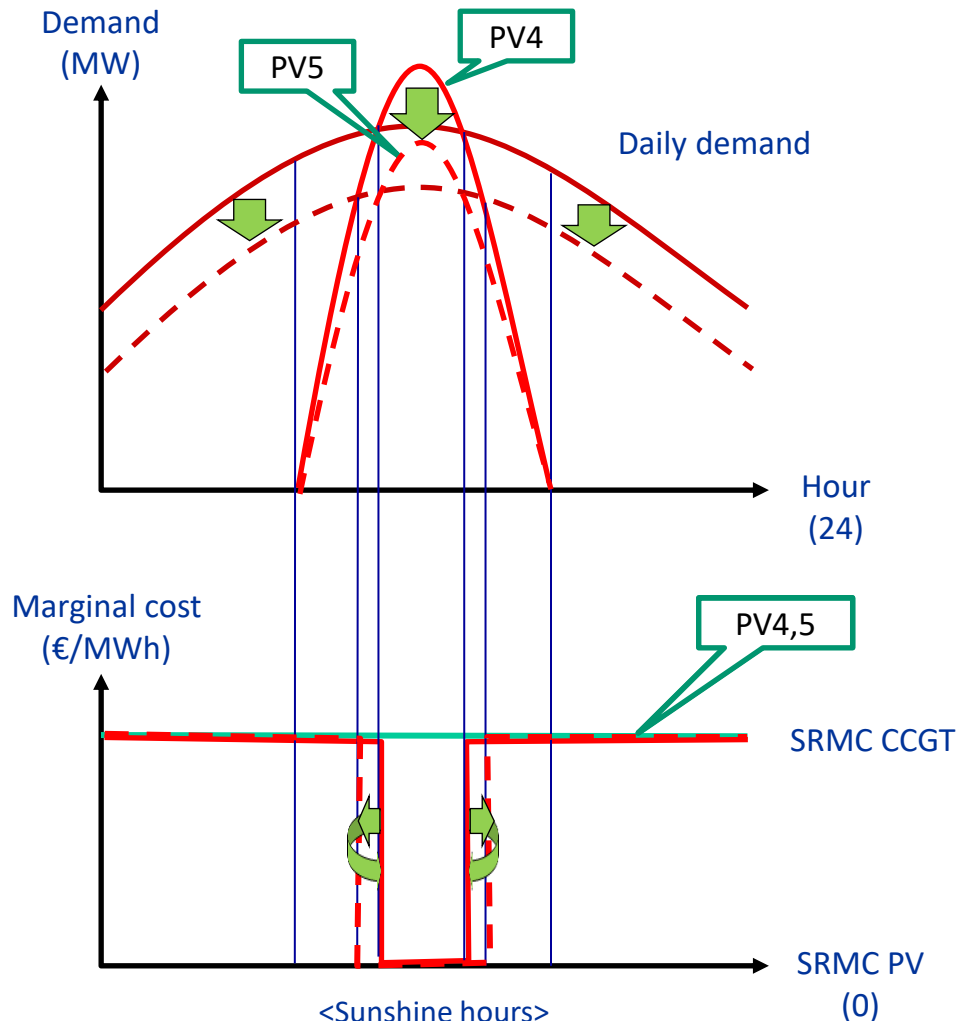
Changing load profile over time

- Charts below profile average hourly demand in May through August 2020-2025. Demand is noticeably lower in the middle of the day. This could be explained by the increase in autoconsumption, mainly rooftop solar.



Source: REE and K4K calcs.

What happens when demand falls?



- If the demand falls and the capacity is equal to that of the starting point, there will be more hours with a low price.
- The solution is to decrease the penetration of PV so that the PV realised price does not fall below the Levelised Cost of Electricity ("LCOE").
- Notice that the distribution of prices (positive vs zero prices) is the same with CCGT retaining pivotal role!

Source: K4K.

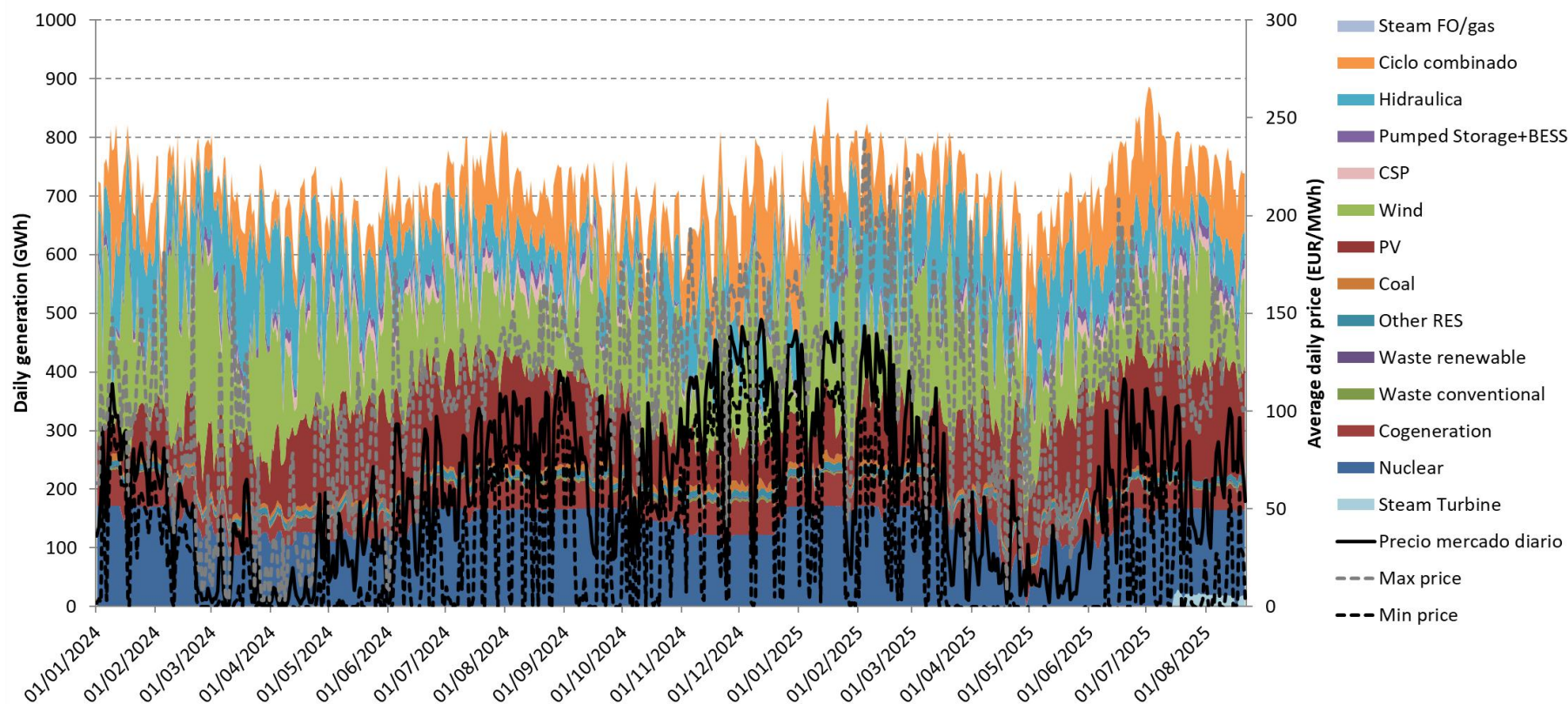
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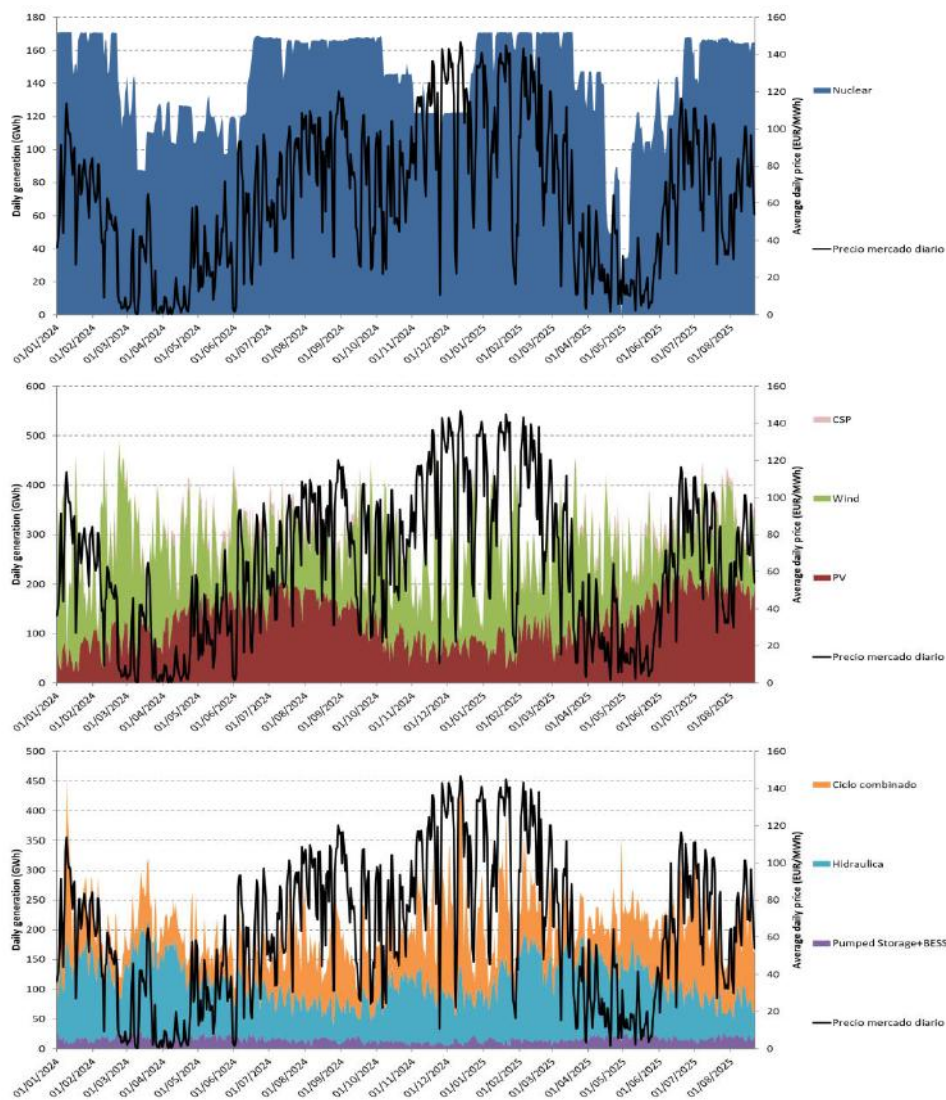
Evolution of generation and prices (1)

- Daily dispatch by technology and average daily spot prices for Spain in 2024-2025. If you look carefully one can see how the market works...
- Note the large amount of wind, flexibility of nuclear, and continuing balancing role of gas-fired CCGT.



Source: REE and ENTSO-E.

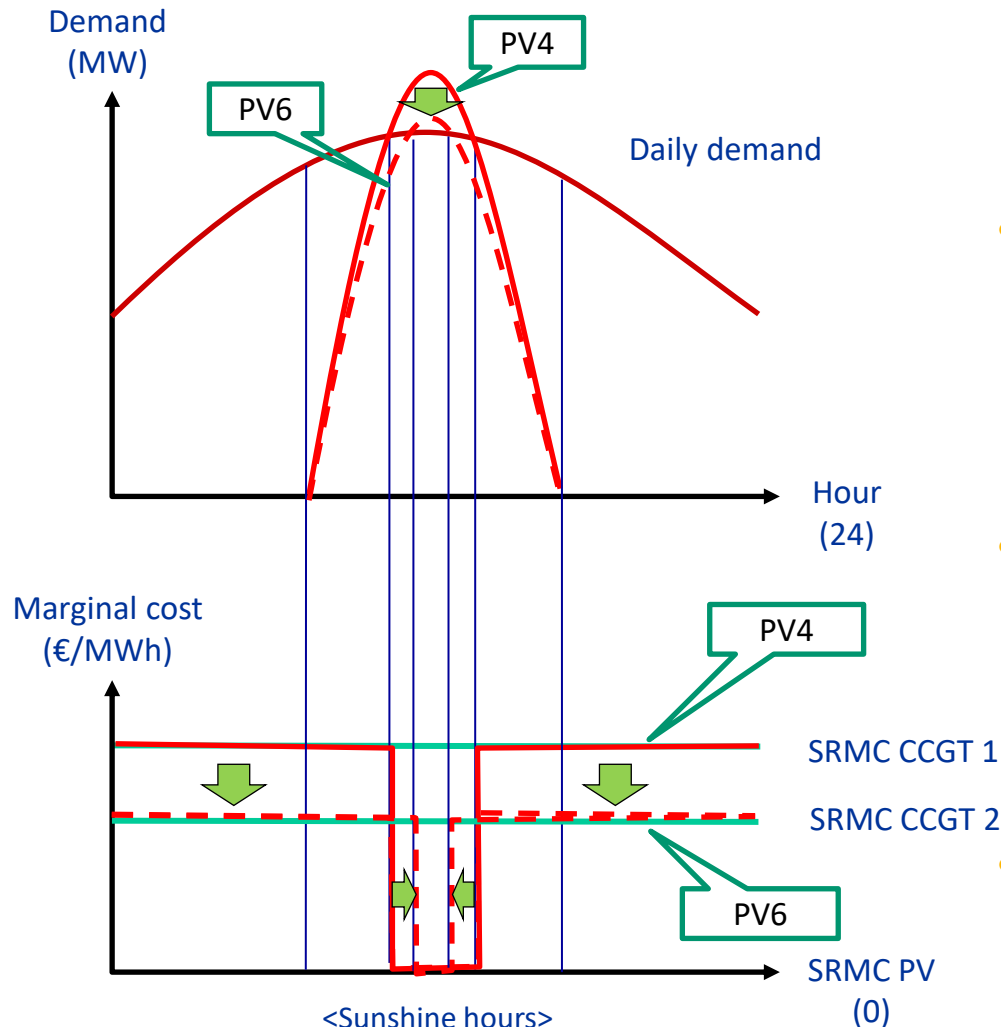
Evolution of generation and prices (2)



- Renewable (especially wind) generation is inversely correlated with average spot prices. You can see the same thing at the hourly level.
- Programming of nuclear generation has proven to be flexible, even if this is less obvious at the hourly level. There is a price below which nuclear might reduce dispatch (~15€/MWh).
- CCGT retains balancing role with prices positively correlated with gas prices:
 - Electricity price (€/MWh) = $2.4 \times \text{gas price (€/MWh(f))}$ before June 2022.
- Flexible hydro always tends to shadow price of next most expensive flexible technology, i.e. CCGT, so dispatch of flexible hydro and CCGT positively correlated with prices. (Note that too much must-run hydro will depress prices.)

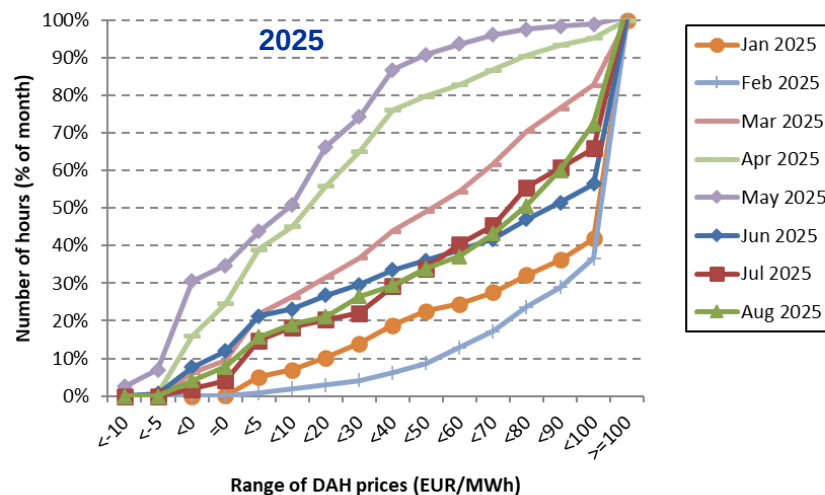
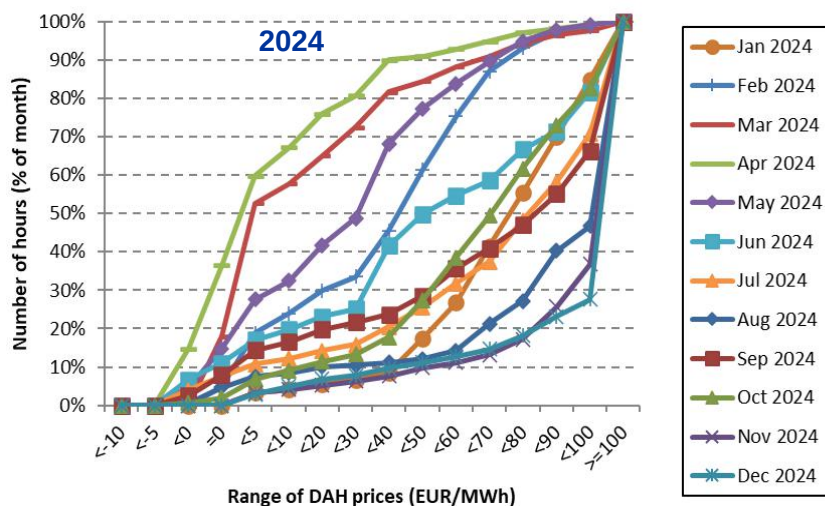
Source: REE and ENTSO-E.

What happens when conventional generation cost falls?



- If the cost of generating with a CCGT falls - caused by a decrease in the price of natural gas or the cost of CO₂ - prices in all hours of PV operation will fall.
- The New PV cannot survive with the same number of very low priced hours, so the penetration of PV must be reduced so that the PV realised price does not fall below the LCOE.
- You have to "close the curtain": the percentage of low prices has to drop enough for the realised price to stabilise at the LCOE. Means market can absorb less PV than before!
- Do we need to reassess 2030 targets and levels of support?

Distribution of hourly DAH pricing is changing rapidly



- As intermittent renewables play a more important role, market prices have dropped with noticeable increase in the number of low prices hours.
- Los precios inferiores a 5EUR/MWh representaron el 6% de las horas en 2023, el 19% en 2024 y ya el 22% en 2025 (hasta finales de agosto).
- In contrast to other European markets, negative prices are uncommon probably explained by greater flexibility in the power system, peculiarity of the Specific Regime to support historical renewables, and increasing use of exemption clause in PPAs that will not clear if prices are zero or negative.

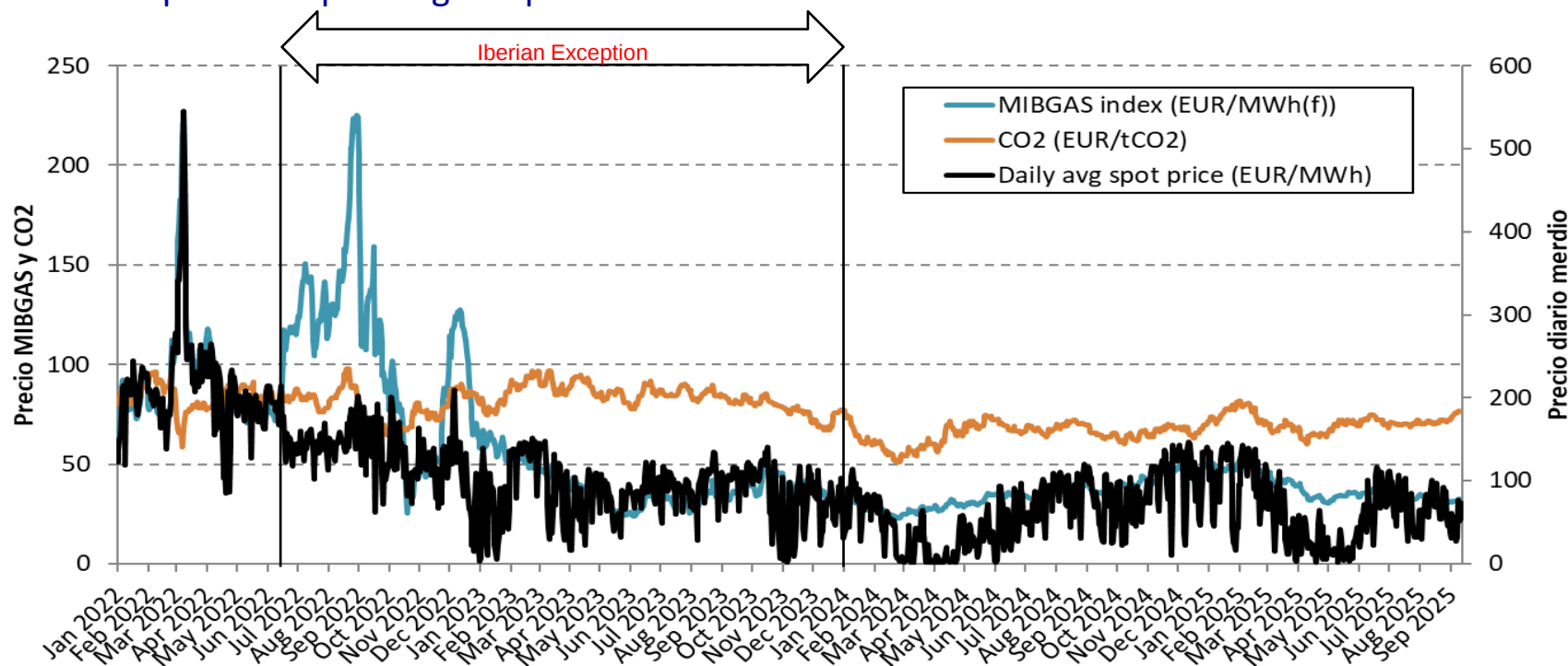
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Higher prices can lead to regulatory intervention

- Spanish government responded to high wholesale prices by implementing series of short-term executive measures including a windfall profit tax (starting with RDL 17/2021) and a cap-on-gas (starting with RDL 10/2022). Both lasted until 31 Dec 2023.
- The cap-on-gas, also known as the “Iberian Exception”, led to a significant reduction in spot prices although it had no effect after 26 Feb 2023 since gas prices were below the regulated gas price. The windfall profit tax had a benign impact on prices although generators would have been impacted depending on specific circumstances.



Source: MIBGAS , ENTSO-E and K4K calcs.

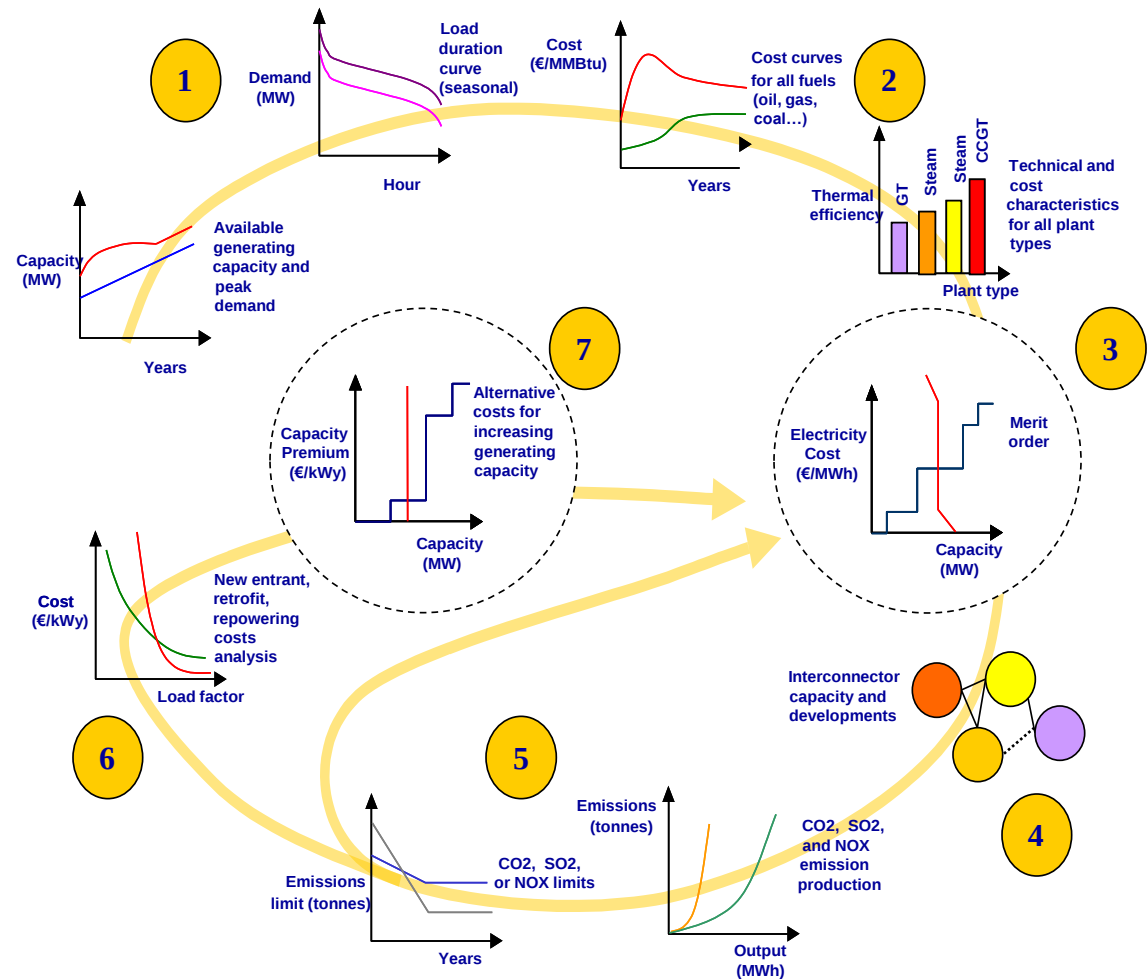
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PMM in a nutshell

- PMM (Power Market Model) is designed to replicate the operations of the actual power system about which one is concerned.
- By including the economic and environmental constraints facing market participants in the real world, PMM replicates how actual decisions are made by stakeholders when subject to any slate of operational constraints, regardless of whether these constraints are physical, economic, or environmental.
- And everything in MS EXCEL.



Modelling innovations adopted for 2025Q3

Every quarter we update a series of standardised inputs which are summarised in the table in the next slide. But from 2024Q2, we have also incorporated a series of additional changes worth highlighting separately:

1. Adopted updated new definition of segments, which rather than only being defined by the ranking of demand, are now defined in terms of the joint ranking of demand, PV and wind generation, thereby capturing extremes.
2. Starting annual capacity in each year based on midyear figure rather than year end to ensure a closer match to historical dispatch.
3. “Autoconsumo” adjustment still included. Demand is modelled on REE data which excludes the impact of behind-the-meter rooftop solar (“RTS”). To reflect additional cannibalisation of demand by RTS, based on APPA data, we have added 8,315MW of RTS by end of 2024 and adjusted REE annual demand upwards to reflect RTS’s contribution based on EOH of 1,197, which would be lower than existing or New PV. We do not increase RTS over time but accommodate it as part of Firm and Economic New PV.
4. Updated 2025 starting annual demand and peak demand based on historical data to date. Thereafter, maintain demand growth=1% in Central and High Cases, and 1.25% in Low Case.
5. Maintain maximum instantaneous dispatch of flexible (pondage) hydro plants (“Pmax”) at $1.5 \times$ minimum dispatch (“Pmin”) to reduce the degree of peak shaving to reduce the degree of intra-seasonal price flattening.
6. Increase lifetime of Specific Regime cogens to 40 years (up from 30 years).
7. Nuclear is must run in line with historical intra-year capacity factors.
8. Adjusted ACFs for New PV and New Wind ensuring a closer match with recent historical data:
 - Existing and New PV ES and PT = 1522, 1566 hours per year, ACF = 17.4%, 17.8%
 - Existing Wind ES and PT = 2010, 2397 hours per year, ACF = 22.9%, 27.4%
 - New Wind ES and PT = 2211, 2517 hours per year, ACF = 25.2%, 28.7%
9. Adjusted downwards TIC New PV and Battery to 650EUR/kW and 900EUR/kW for New Wind.
10. Adjust ACF for Low and High Cases to ensure the LCOE of New PV and Wind was similar to 2025Q3.
11. Gas TPA tariff reverted to 2EUR/MWh(f) since would otherwise result in higher baseload and realised prices than observed historically.
12. Economic New Battery allowed from 2026 at 2GW per year until 2030 and uncapped thereafter.

Overview of Sensitivities

	Low Case (Low1_20250822)	Central Case (Ref1_20250822)	High Case (High1_20250822)
Fuel prices	Gas price cap, MIBGAS/TTF until 2027, CME futures	MIBGAS/TTF until 2027, CME futures	MIBGAS/TTF until 2027, CME futures
CO2 (EUA prices)	ICE futures	ICE futures	IEA WEO 2024 Announced Pledges
Domestic coal surcharge	None	None	Applied
IED coal output cap	None	None	Annual output caps applied
Generation Tax (7%)	7.0% in '25 only	7.0% in '25, 3.5% in '26 only	7.0% in '25, 3.5% in '26 only
Demand growth	1.25%	1.0%	1.0%
Green Cent Tax	None	Applied to Coal	Applied to Coal
Annual hours for New PV	1750 (*115%)	1522	1446 (*95%)
Annual hours for New Wind	2312 (*105%)	2211	1910 (*86%)
TIC of New Wind , PV and Battery (€/kW)	-20%	900/650/650	900/650/650
Annual cap on economic New Wind/PV	3/4GW from 2025, uncapped from 2031	2.0/2.0GW from 2025	2.0/2.0GW from 2025

Most important

- NECP growth rates. Brent, coal and CO2 prices based on CME and ICE futures. Gas indexed to oil from 2028 but linked to MIBGAS in 2025-2026 and TTF in 2027. RDL 10/2022 gas-indexed subsidy extended in LC although low gas prices mean no impact.
- HC applies coal transportation surcharge for domestic coal and a more restrictive view of Industrial Emissions Directive (“IED”).
- Generation tax removed due to over-recovery in 2021-2022 and national fund (FNSSE).
- “Firm” additions in 2025 of 2.0GW New PV all cases. Apply annual caps on the deployment of other “economic” New Wind and PV until 2030 in the Low Case but forever in other cases. 2GW cap on New Battery from 2026, uncapped from 2031.

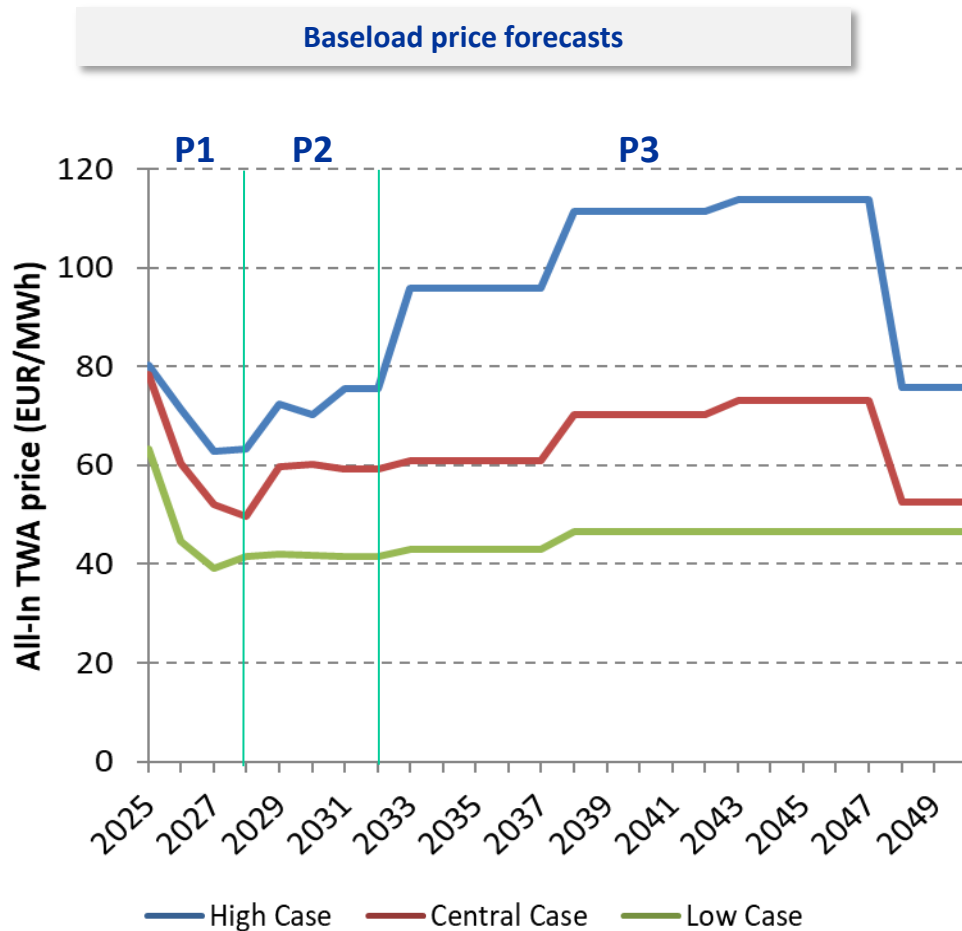
Note: Prices real 2025€.

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Market price forecasts

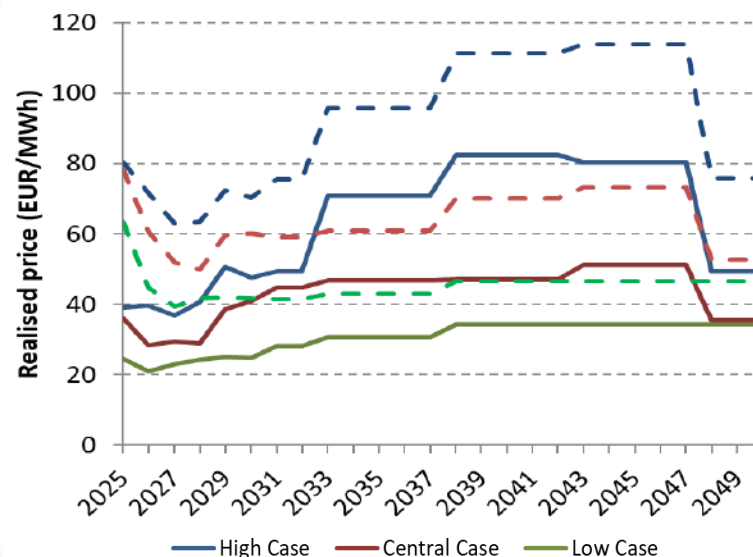


- Prices first move in line with commodity prices and adjust to new additions (P1) and then plateau (P2).
- As a lot of thermal capacity retires in the 2030s, a step-up in prices is expected in the Central and High Cases (P3).
- But even in these cases, renewable capacity eventually catches up and prices drop.

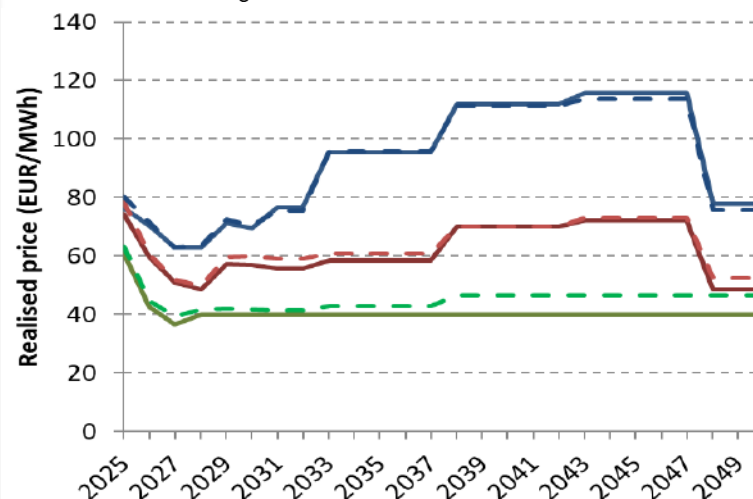
Realised price forecasts

- Wind Capture Price tracks the baseload price. The adoption of the new load duration curve approach has had a profound negative impact on daytime prices and hence the PV Capture Price. Only a slow down in the deployment of New PV leads to price recovery from 2029.
- K4K remains optimistic that profitability of renewables will be satisfactory. But we are also more pessimistic since we do not believe that market conditions (grid and planning constraints, project "bankability", liquidity of PPAs, etc.) are adequate to reach the government's aggressive capacity goals under the NECP.

PV Capture Price



Wind Capture Price

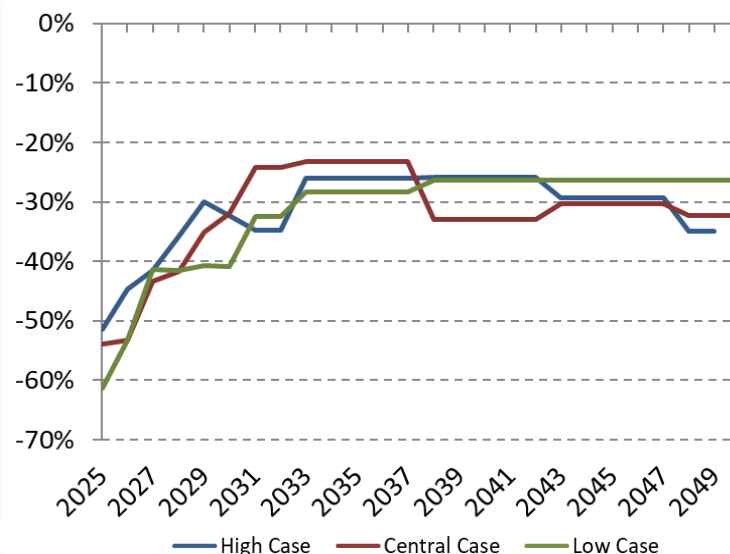


Source: K4K 2025Q3. Prices real 2025€. Dashed line = Baseload prices.

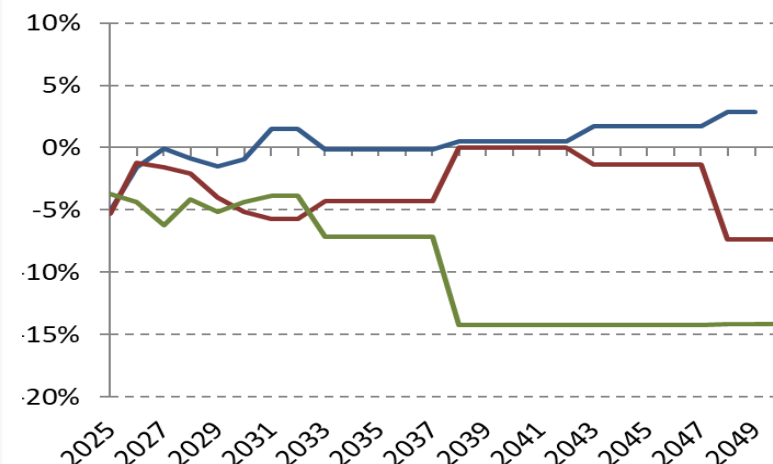
PV and Wind capture price spreads

- K4K predicts that the PV Capture Price Spread will remain low over the next few years before recovering and stabilising at ~30%. The Wind Capture Price Spread will fall far less.
- If realised prices fall below LCOE, no capacity will be deployed until demand grows sufficiently. Then New PV and New Wind capacity will be deployed until the Capture Prices converge on their LCOEs.
- Note that since New Wind is “quasi-baseload” (since the wind blows both during the day and at night), then
 - Wind Capture Price Spread = ~0
 - PV Capture Price Spread = $\sim(\text{LCOE PV} - \text{LCOE Wind}) / \text{LCOE Wind}$

PV Capture Price Spread



Wind Capture Price Spread



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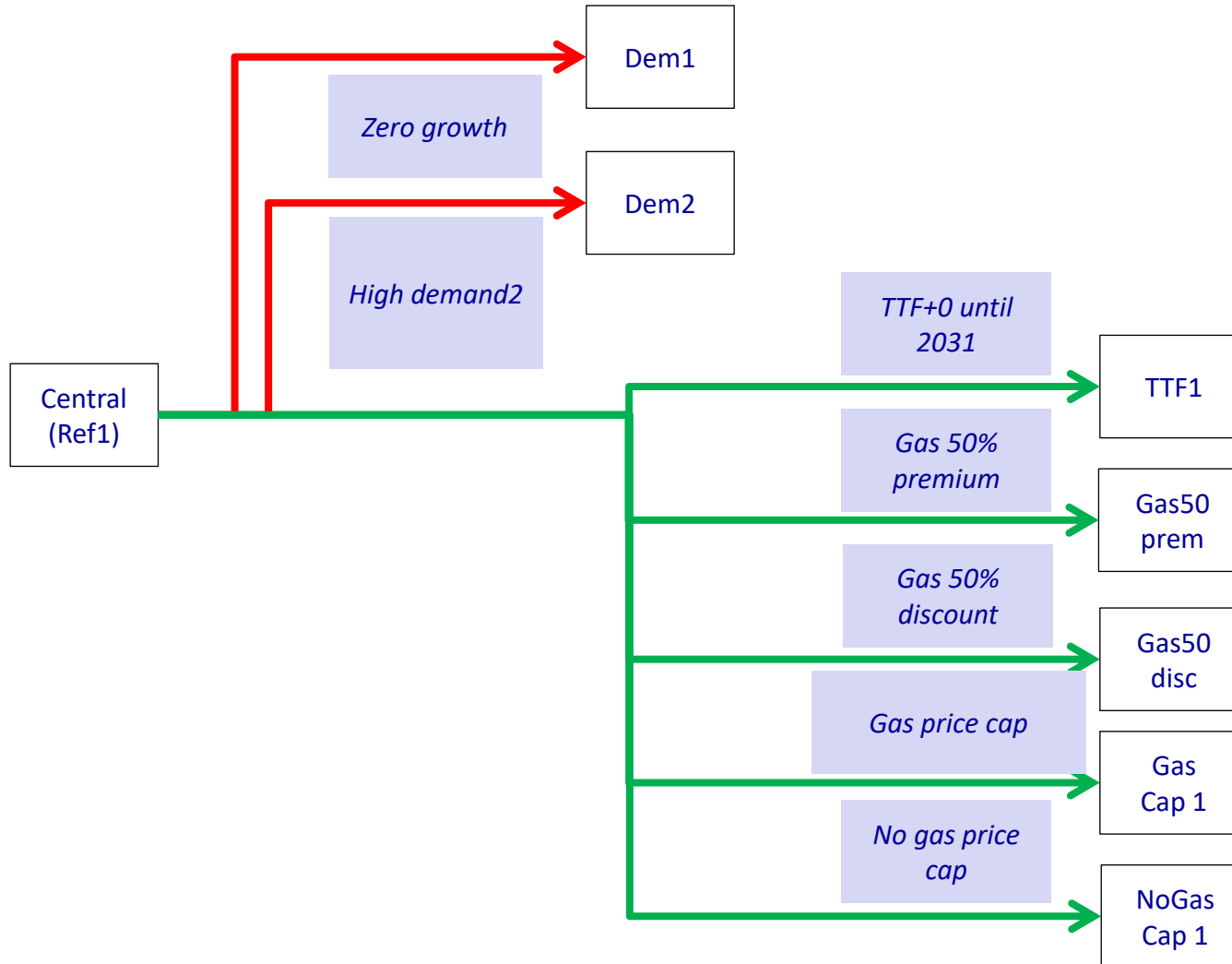
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Using the PMM to test different hypotheses

- We had plenty of questions at the end of this exercise so we went ahead and ran some path-specific sensitivities to explore what could affect market and realised prices most. This was done by defining a series of changes - shown below - and applying them in a cumulative manner to the Central and Low Cases. We also defined two Combined Cases.

Change applied	Explanation
High demand1	Demand as in Low1.
High demand2	2.5% growth 2025-2035 and 2.0% thereafter, reaching 1.5x CC demand by 2050.
Zero growth	Zero demand growth.
Firm New Build 1	Add 1.5/2.0GW annually until 2030 of Firm New Wind/PV (additional to Economic New Build limits).
Firm New Build 2	Add 1.5/7.0GW annually until 2025 of Firm New Wind/PV (additional to Economic New Build limits).
Uncap from 2025	Uncap Economic New Builds from 2025 onwards.
X/YGW(+) annual caps	Annual caps of New Wind XGW and New PV YGW, uncapped from 2031 if followed by "+".
RES target	Set generation requirement from RES to 70% of total demand in 2030 and increase to 95% in 2050. (If binding, we can track the price of renewable certificates ("REC"). Remember there is no "missing money" problem in our cases: if prices dip, income will be made up by RECs.)
High ACF for New RES	Increase annual hours of New Wind and New PV to 2312 and 1750 respectively.
Low TIC (-X%)	Reduce the TIC of New Wind, PV, and Battery by percentage shown relative to the Ref1 case.
TIC (gradual) step-down	€/kW 2025-2050: New Wind=882 to 652, New PV and New Battery =624 to 340.
No RES closure	Never close the existing RES (and cogens).
Endogenous closure	Allow model to close Coal, CCGT, and Nuclear on economic basis.
Gas X discount/premium	Discount /premium on delivered gas price.
Gas price cap	Treatment of RDL 10/2022 (extension or not).
TTF until 2031	TTF commodity price until 2031.
Hydro ACF	Up or down by 25%.
RMC of New Wind and PV	RMC1 halves RMC so New PV=7.5% and New Wind =16%, whilst RMC2 set both to zero.

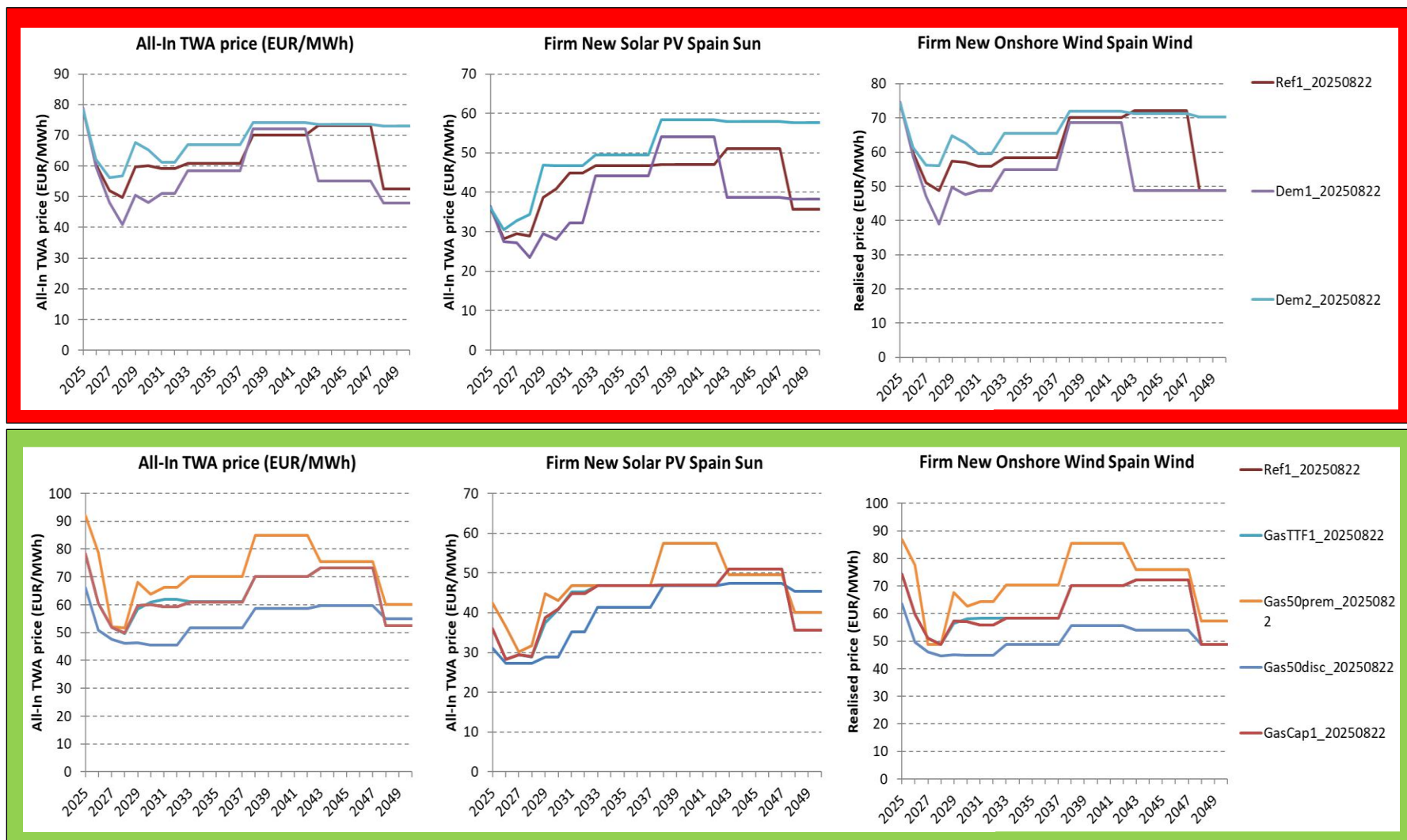
Defining modelling paths (1-2)



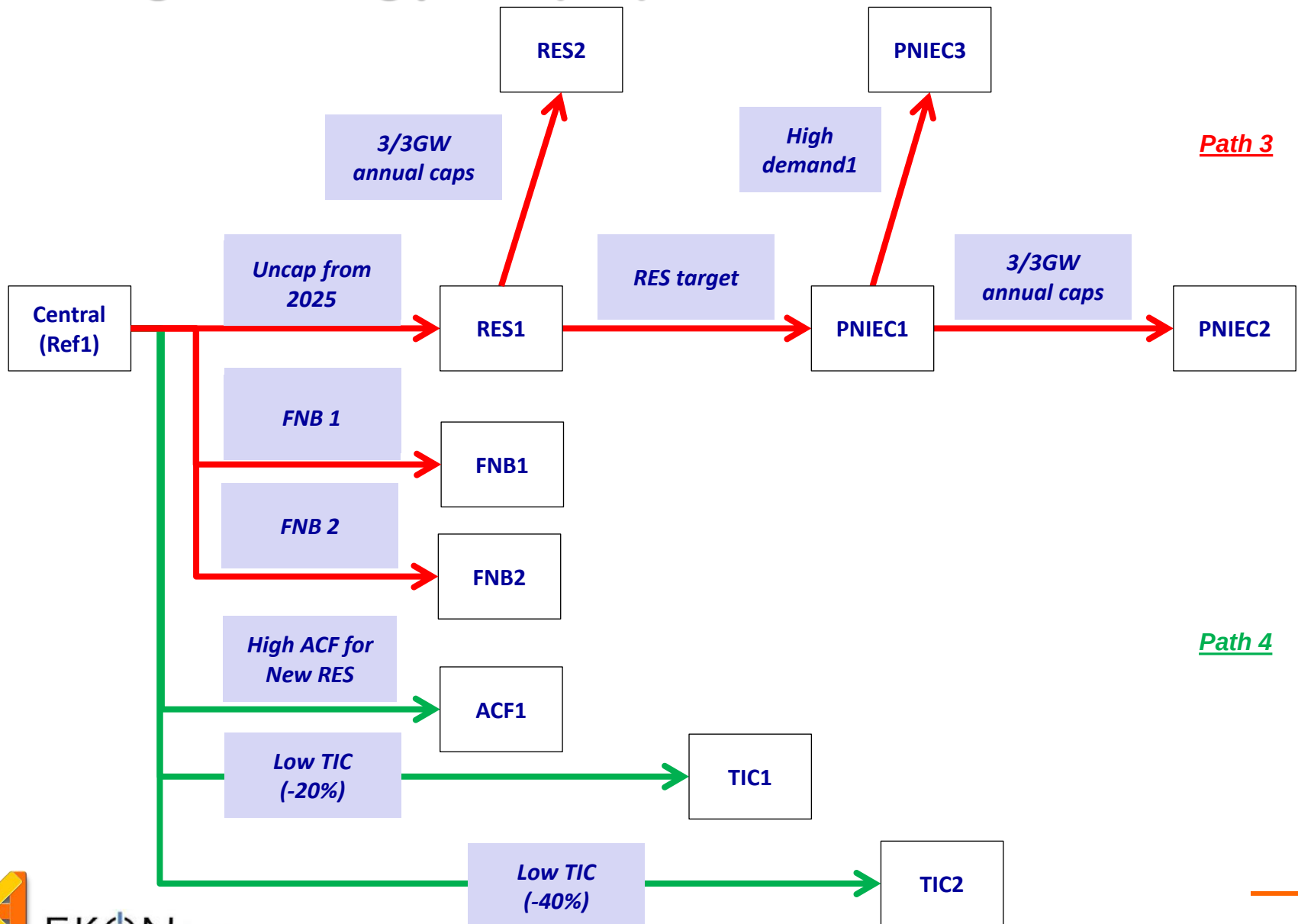
Path 1

Path 2

Sensitivity results (path 1-2)



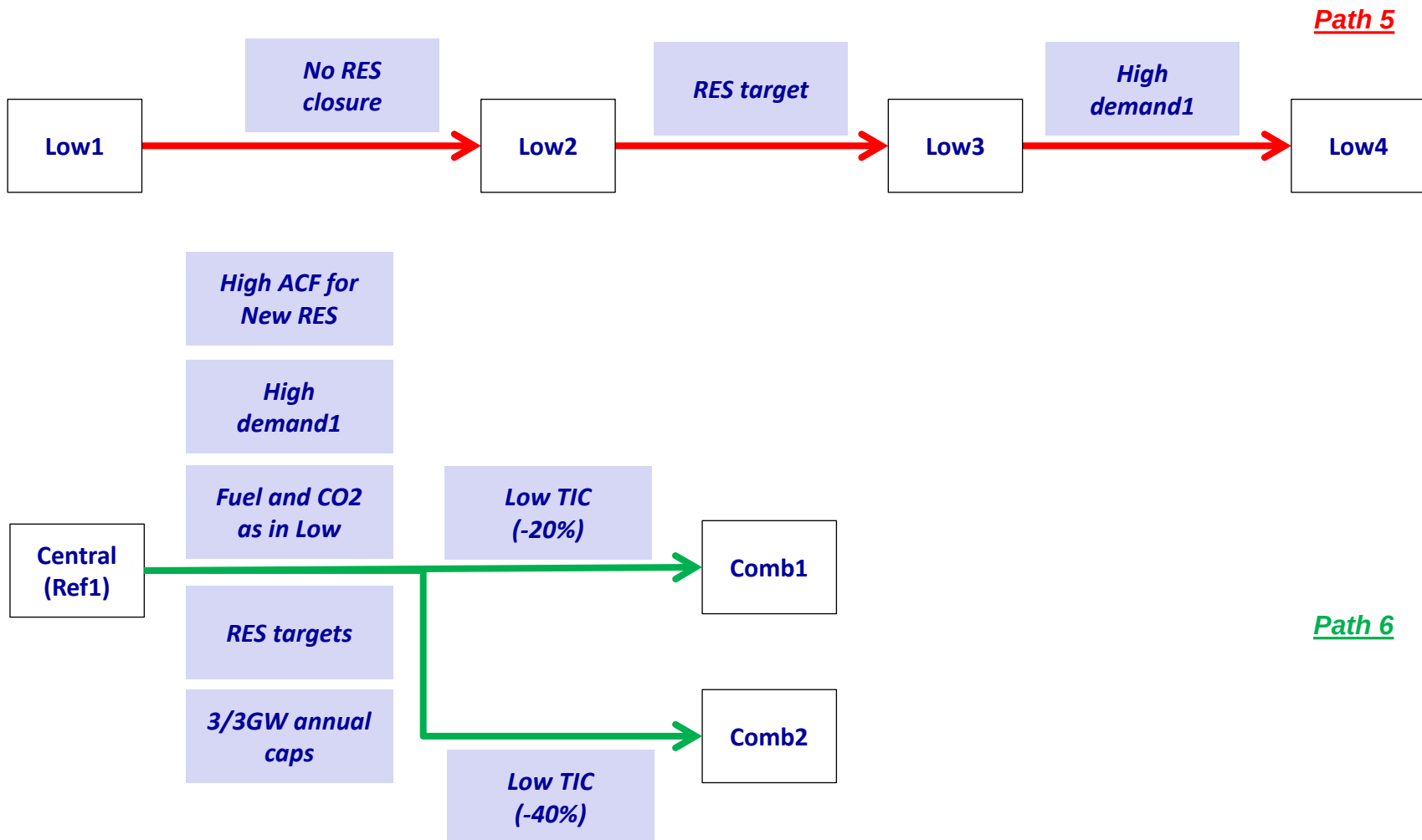
Defining modelling paths (3-4)



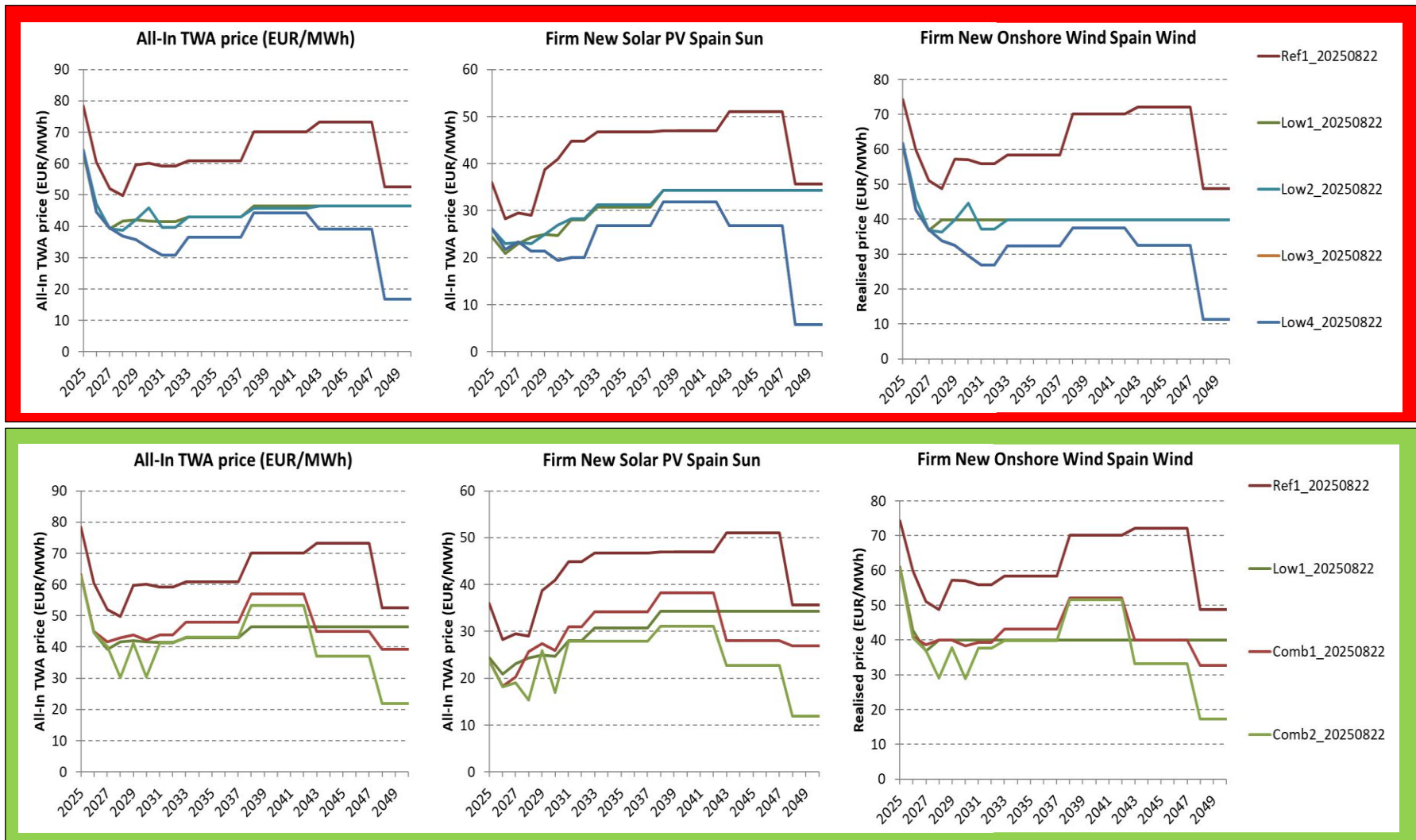
Sensitivity results (path 3-4)



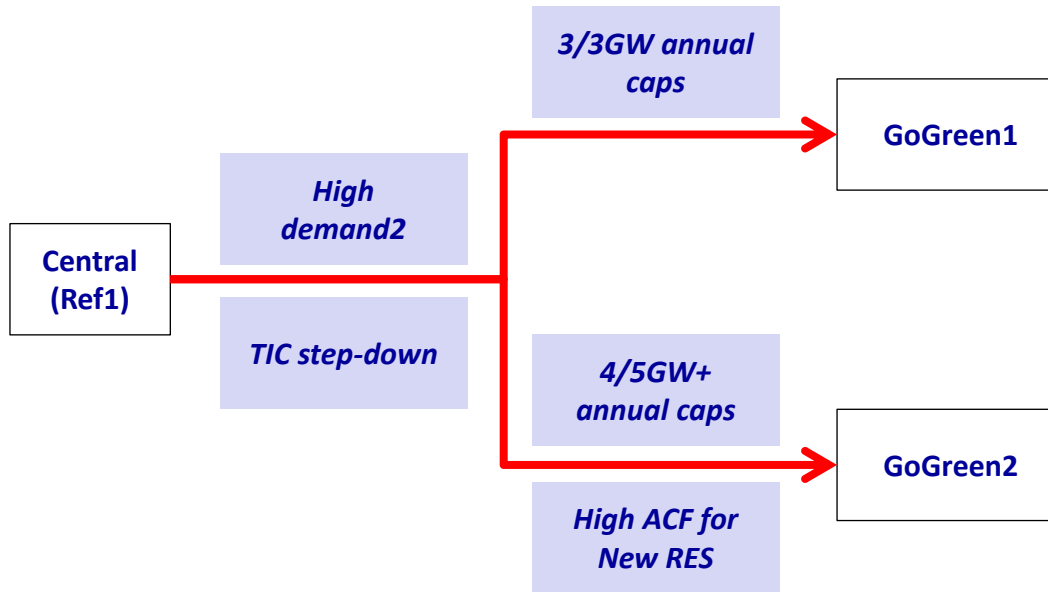
Defining modelling paths (5-6)



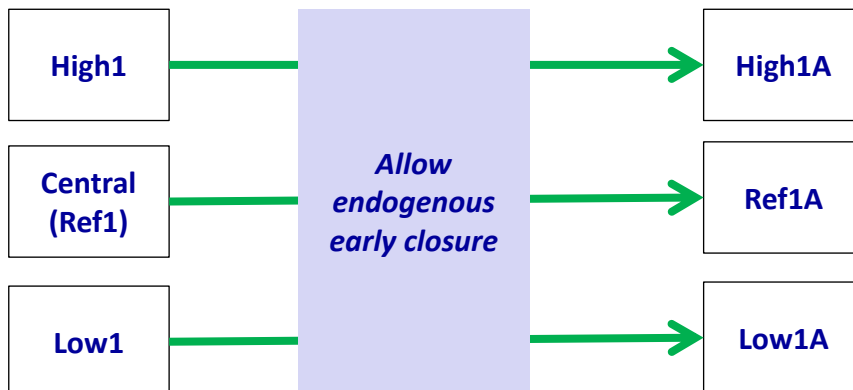
Sensitivity results (path 5-6)



Defining modelling paths (7-8)

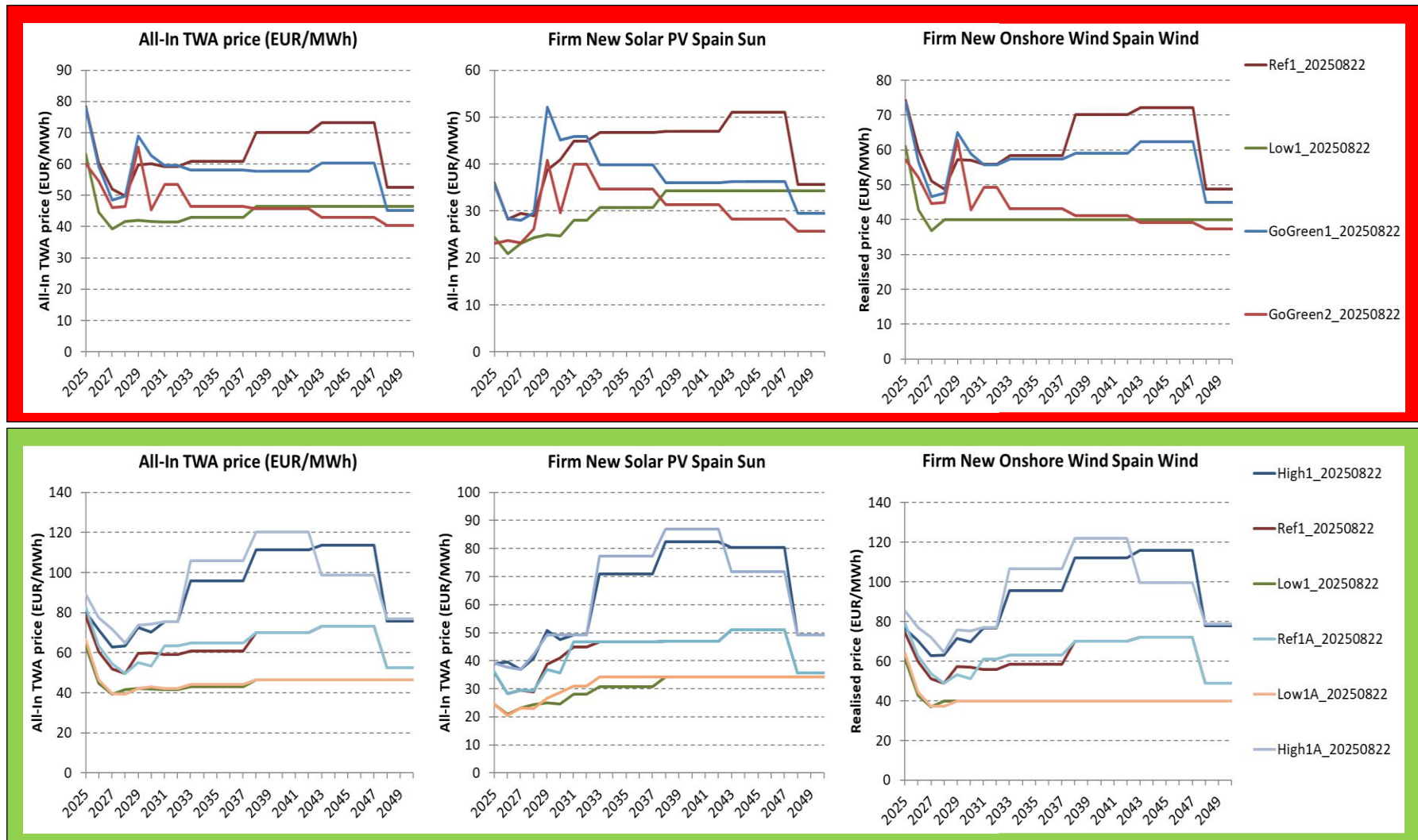


Path 7



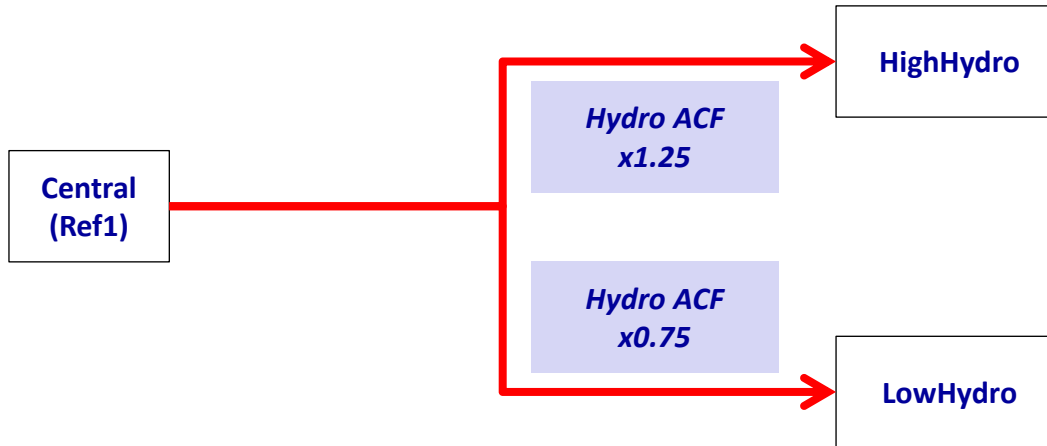
Path 8

Sensitivity results (path 7-8)

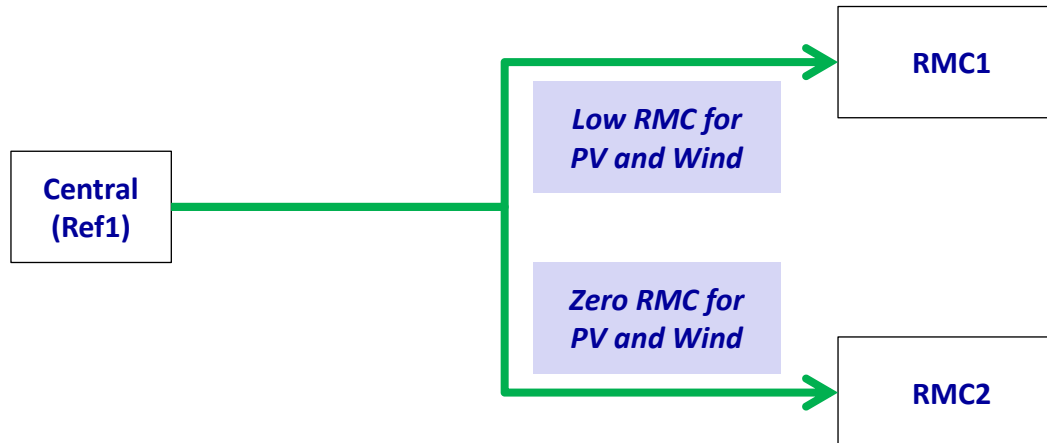


Defining modelling paths (9-10)

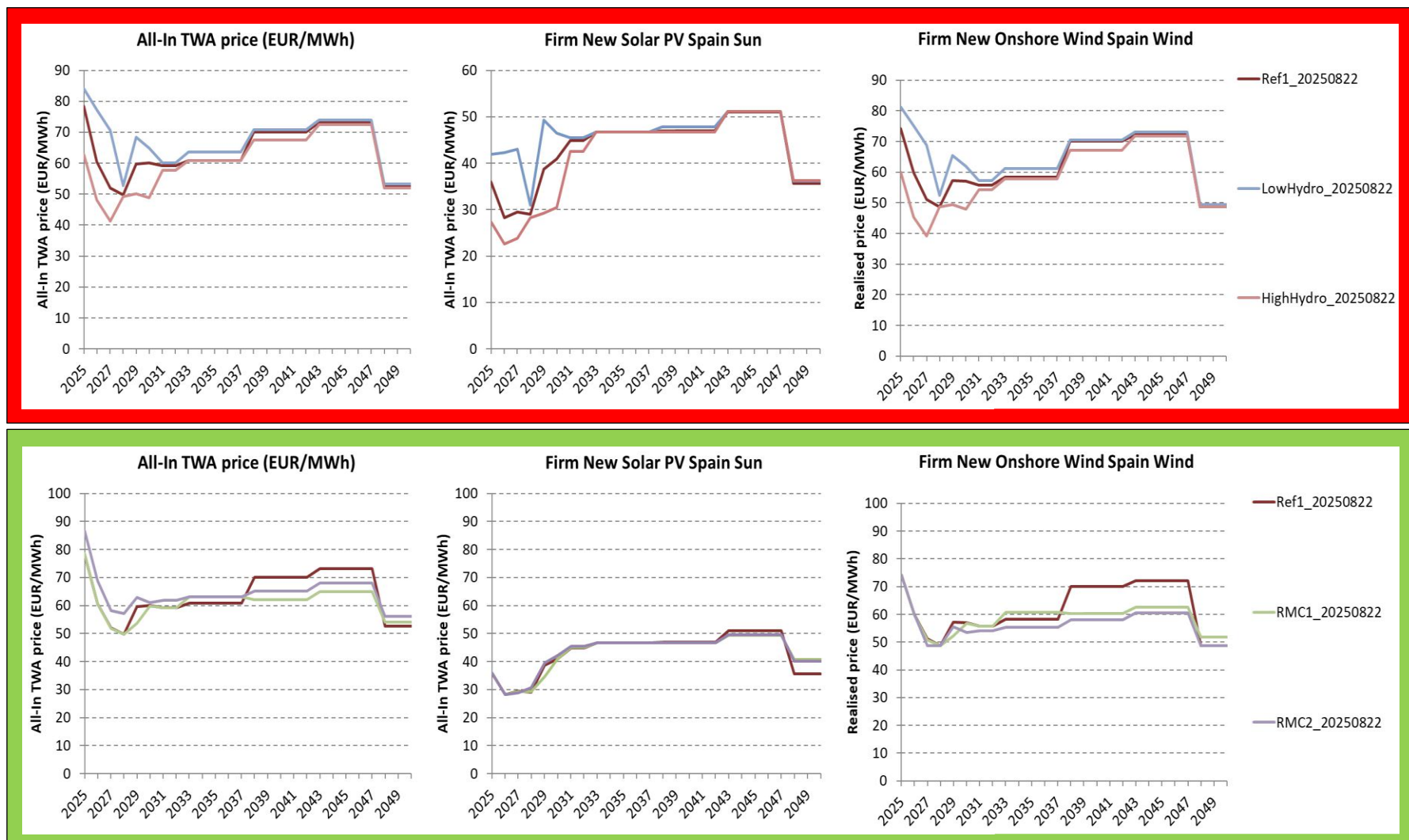
Path 9



Path 10



Sensitivity results (path 9-10)



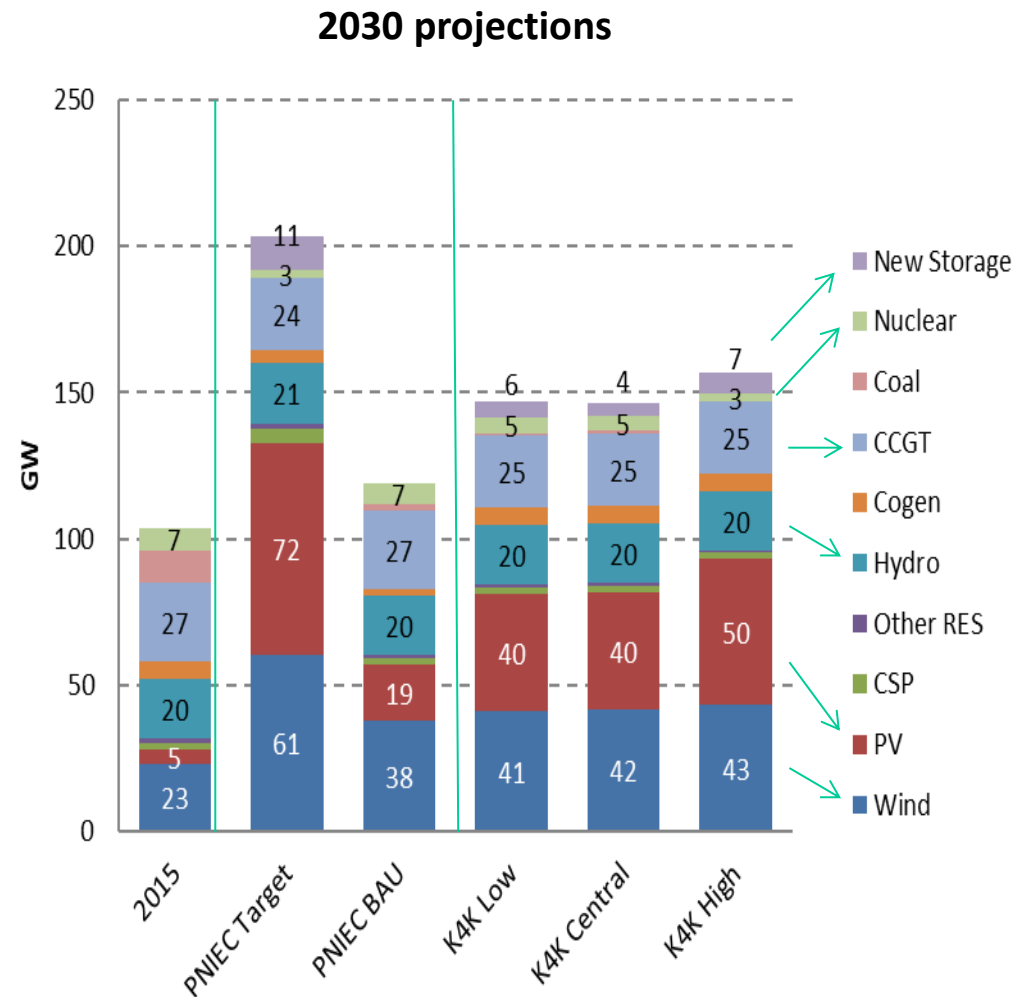
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Achieving the NECP 2030 targets

- Share of renewable generation in K4K Central Case is 71.70% and 73.37% in the Low Case (compared to 81% target in new NECP).
- NECP capacity targets very aggressive since requires significant increase in demand, historical hours for renewables, and massive increase in exports.
- What if the government pursues aggressive targets that exceed saturation point?
 - Auctions for new capacity only will undermine merchant market and be open to legal challenge for discrimination.
 - Better to use market for green certificates with firm targets and open to all. (With bonus of no “missing money” problem even if one exceeds saturation points.)



Note : Hydro includes pumped storage.

Source: Plan Nacional Integrado de Energía y Clima 2023-2030 (“PNIEC”) 2024, Mainland figures only, K4K 2025Q3.

And beware PNIEC assumptions

Figura D.7. Resultados Escenario Objetivo H2030

Escenario Objetivo H2030. Plan de Energía y Cambio Climático.

España Peninsular

Generacion mínima síncrona:

3N+7 Térmicas

Cod 01_2030

La demanda en ES (TWh):

263

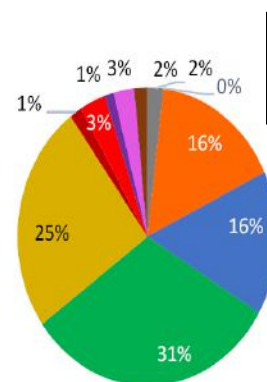
Demanda punta (MW):

47,768

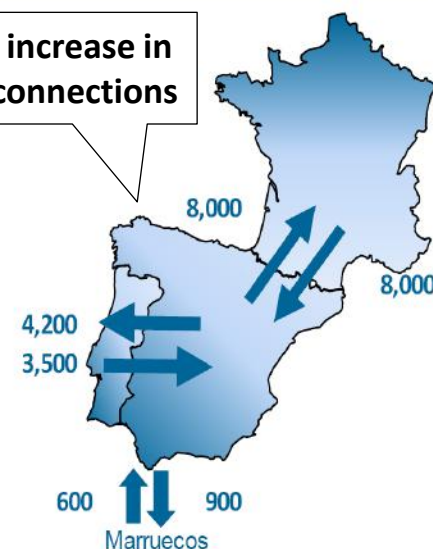
Capacidad instalada en España (MW)

Capacidad de intercambio (MW)

	MW	%
Nuclear	3,050	2%
Carbón	0	0%
Ciclos	24,560	16%
Hidráulica (+ bombeo)	24,140	16%
Eólica	48,550	31%
Solar FV	38,404	25%
Termosolar	2,300	1%
Termosolar almacen. 9h	5,000	3%
Resto RES	1,730	1%
Cogeneración y otros	3,980	3%
Baterías	2,500	2%
Total sistema eléctrico	154,214	100%



Note increase in interconnections



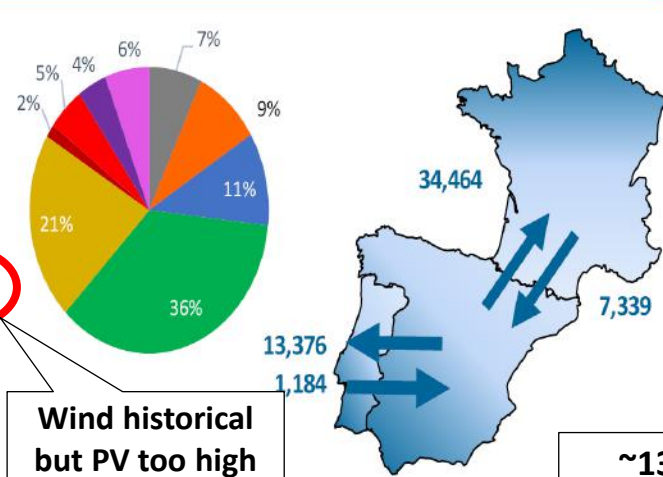
Capacity may not need to be that high

Balance de generación (GWh). España peninsular

Saldo de intercambios anual (GWh)

	GWh	%	Horas utilización
Nuclear	22,034	7%	7,224
Carbón	0	0%	0
Ciclos	27,617	9%	1,124
Hidráulica	32,376	11%	1,341
Eólica	109,464	36%	2,255
Solar FV	65,180	21%	1,697
Termosolar	4,629	2%	2,013
Termosolar almacen. 9h	15,156	5%	3,031
Resto RES	12,088	4%	6,987
Cogeneración y otros	18,399	6%	4,623
Generación	306,943	100%	

Balance almacenamiento	-4,964
Consumo almacenamiento	22,042
Producción bombeo	13,782
Producción baterías	3,296



Perfil exportador con Marruecos: 0	
Saldo ES-FR	27,125
Saldo ES-PT:	12,192
Saldo Neto + Marruecos:	39,317
CONGESTIONES (% horas)	ES EXPORT
ES-FR	53.2% 8.6%
ES-PT	8.0% 0.7%
Spread ES-FR (€/MWh):	23.4

~13% of generation for export?

Draft PNIEC even more unlikely

Escenario Objetivo H2030. Plan de Energía y Cambio Climático.

España Peninsular

Generación mínima síncrona:

7 CC + 3 NUC

Cod 2030_600

Demanda (TWh):

344.0

+31% and +13% respectively

Punta horaria de demanda (MW):

53794

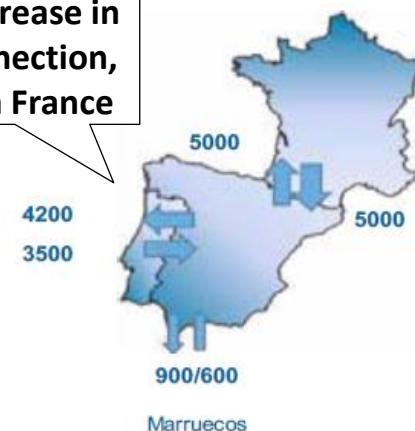
Capacidad instalada (MW)

Capacidad de intercambio (MW)

	MW	%
Nuclear	3041	1%
Carbón	0	0%
Ciclos	24499	12%
Hidráulica (sin bombeo)	14562	7%
Eólica terrestre	57737	28%
Eólica offshore	2800	1%
Solar FV	72130	35%
Termosolar	4804	2%
Resto RES	1964	1%
Cogeneración y otros	4205	2%
Almacenamiento	17612	9%
Total sistema	203353	100%
Electrolizadores	11980	

Target PV +88%
and Wind +19%

Same increase in
interconnection,
less with France



Información adicional:

Potencia renovable en España peninsular (MW)

153997

76%

del Total sistema

Source: Updated PNIEC (2024) Annex D.

Generation and capacity probably too high

Balance de generación (GWh)

	GWh	%	Horas utilización
Nuclear	36881	10%	7224
Carbón	0	0%	0
Ciclos	19750	5%	806
Hidráulica (sin bombeo)	28932	8%	1987
Eólica terrestre	117450	31%	2034
Eólica offshore	9695	3%	3463
Solar FV	125377	33%	1738
Termosolar	11426	3%	2378
Resto RES	10993	3%	5597
Cogeneración y otros	17859	5%	4247
Generación ⁽¹⁾	378362	100%	

⁽¹⁾ Sin almacenamiento

Balance almacenamiento	-7185	GWh
Consumo	35447	
Producción	28262	

Reversal of flows with PT
but FR takes up the slack

PV too high but
wind lower

More
reasonable 7%
of generation?

	GWh
Saldo ES-FR	-30961
Saldo ES-PT:	5083
Saldo neto internacional (FR, PT, MA)	-27243
Positivo: saldo importador. Negativo: saldo exportador.	
CONGESTIONES (% horas)	
ES-FR	76.7% → 7.5%
ES-PT	3% ← 19%
Spread ES-FR (€/MWh) ⁽³⁾	27.4

⁽³⁾ Media horaria de la diferencia de precios en cada hora en valor absoluto

Spanish Electricity Price Dynamics



- Background
- Key concepts
- Review of recent events
- Modelling assumptions
- Modelling results
- Thoughts on PNIEC
- Final comments

Final comments

- What if government targets capacity that exceeds saturation points, as seems likely? Let's hope they don't discriminate between different cohorts of assets! Setting an aggressive green energy target (GWh) and backing this up with tradable green certificates would ensure that all investors - old and new - are protected from the inevitable electricity price crash.
- So get informed and if you want to take a view on realised prices for PV or wind, think about these:

- Demand growth

← **Re saturation point**

- Fuel prices

- EUA prices

← **Short-term impact**

- Taxes (Generation Tax, Green Cent Tax)

- Lifetime limit for existing plants (cogeneration and renewables included)

- Hydrology

- Operational hours for New Wind and PV

- Capex, leverage and cost of capital of New Wind and PV

- Rate of deployment of New Wind and PV (including rooftop)

- Measures to meet PNIEC targets (including auctions)

← **Especially important**