Spanish wholesale electricity price dynamics

2 September 2026

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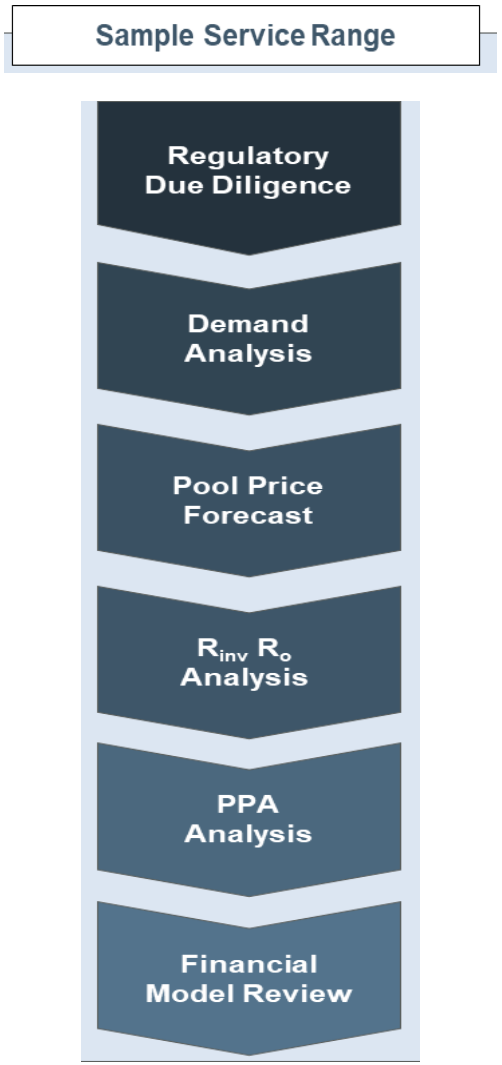
K4K services

- 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 80GW with a transaction value of US$50 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.



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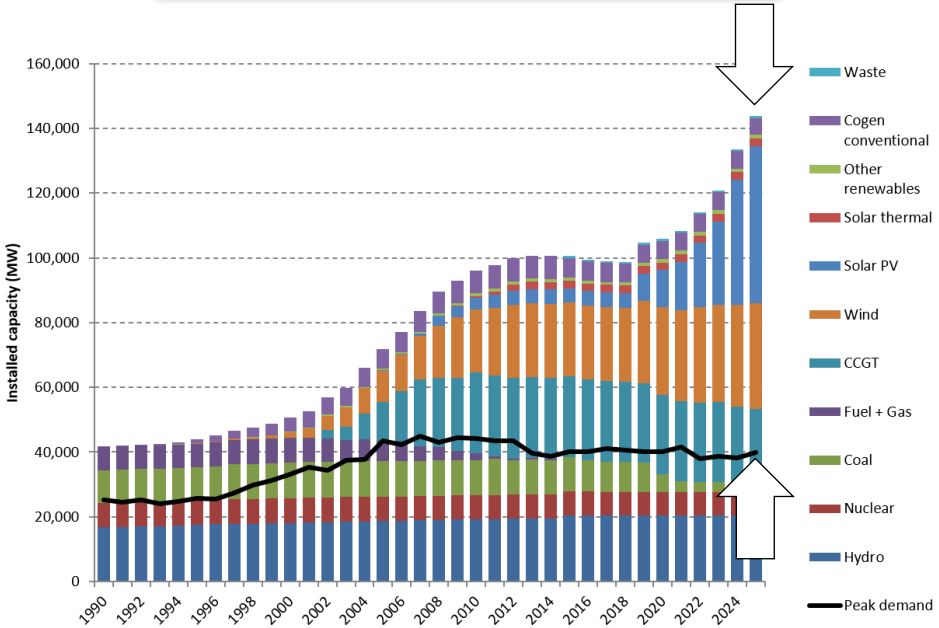
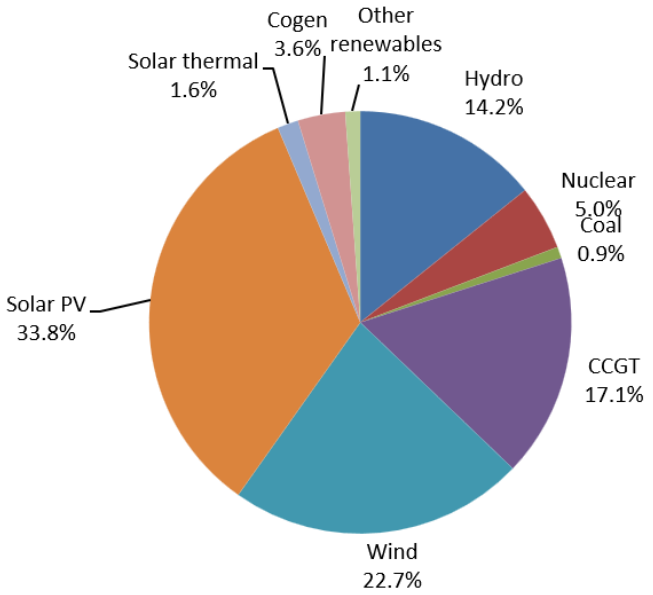
Historical capacity mix

- We are not building renewables because the lights are about to go out…

Evolution of installed capacity



Capacity mix (end 2025)



Source: REE and K4K calcs.

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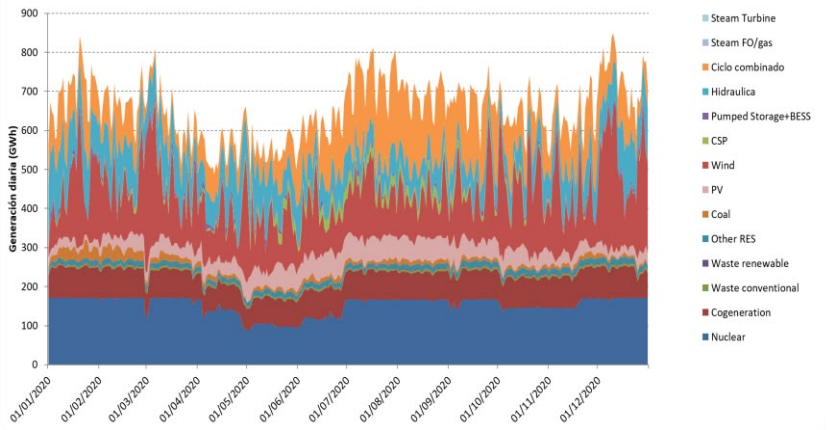
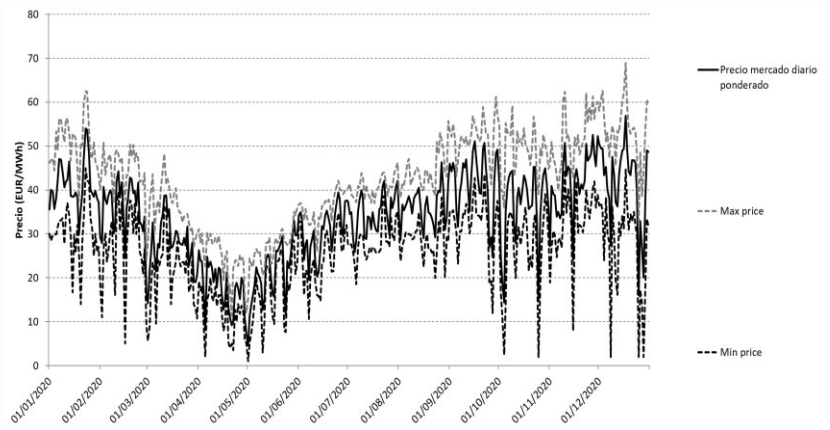
What to make of market outcomes?

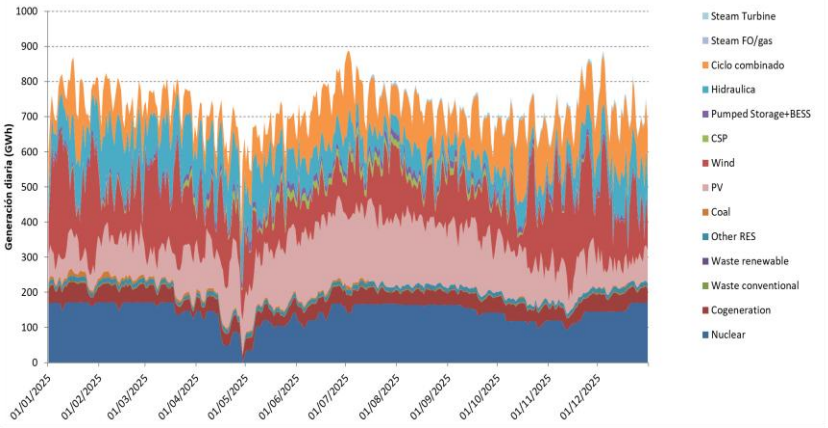
- Hourly data for 2020 and 2025 show volatility of market prices and generation.

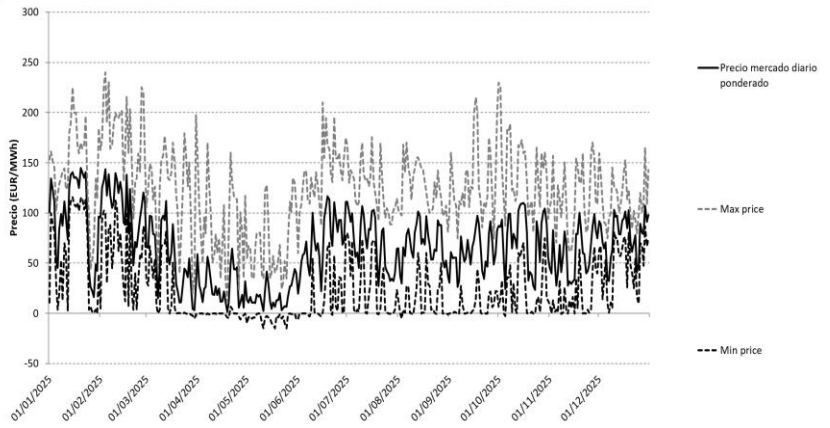
2020





2025





Source: REE ESIOS.

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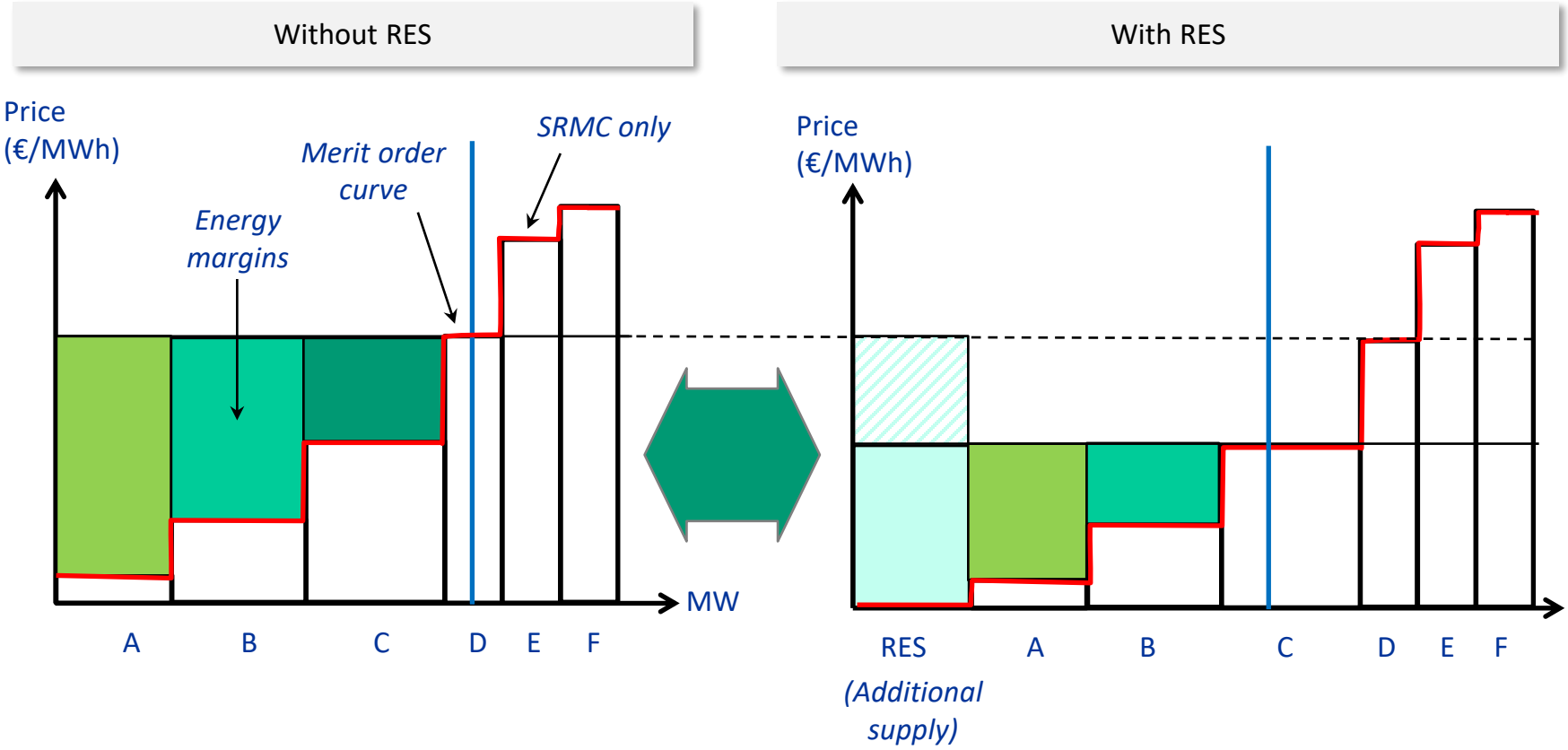
The chicken (duck?) and egg problem…

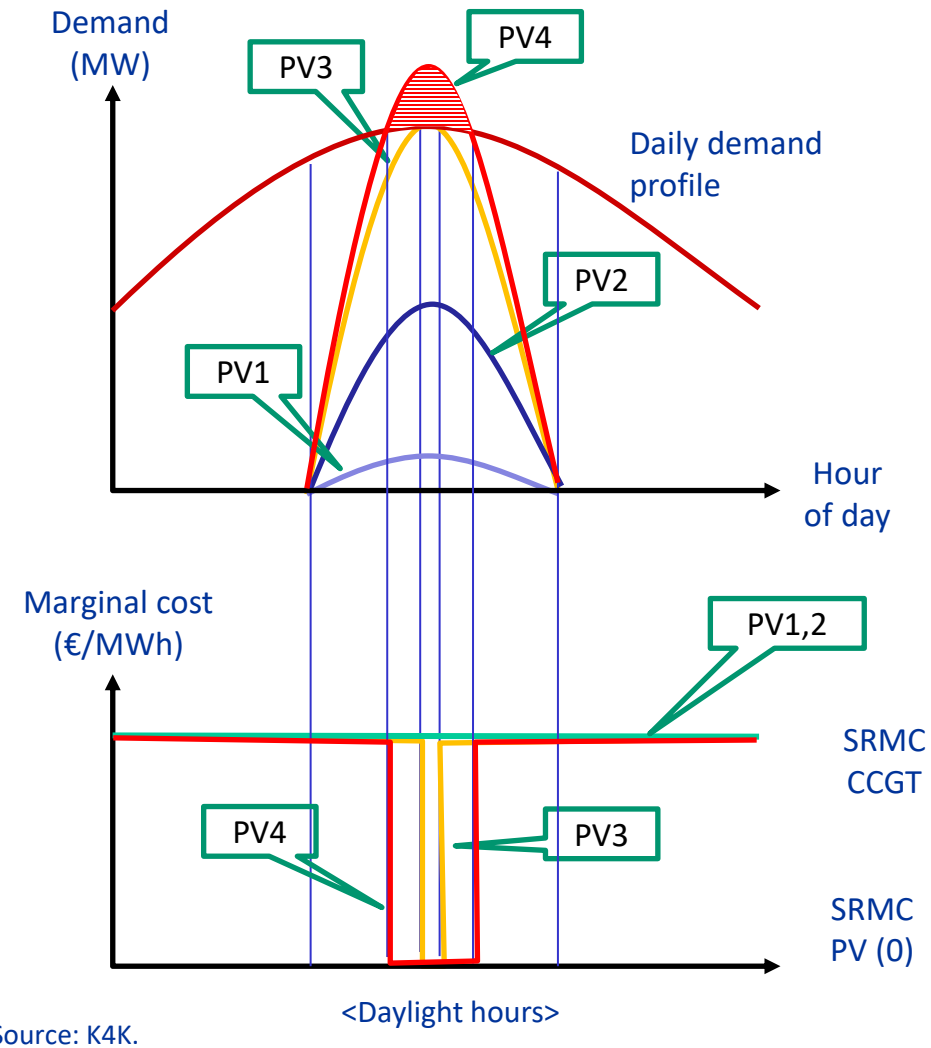
- Market participants make an assessment of profits from the energy market. Renewables energy sources ("RES") are price takers but will still affect market outcomes thereby reducing their remuneration the more they produce.



Source: K4K.

Recap https://www.youtube.com/watch?v=pHrUIGTlqt4.

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.)

Source: K4K.

Recap https://www.youtube.com/watch?v=pHrUIGTlqt4.

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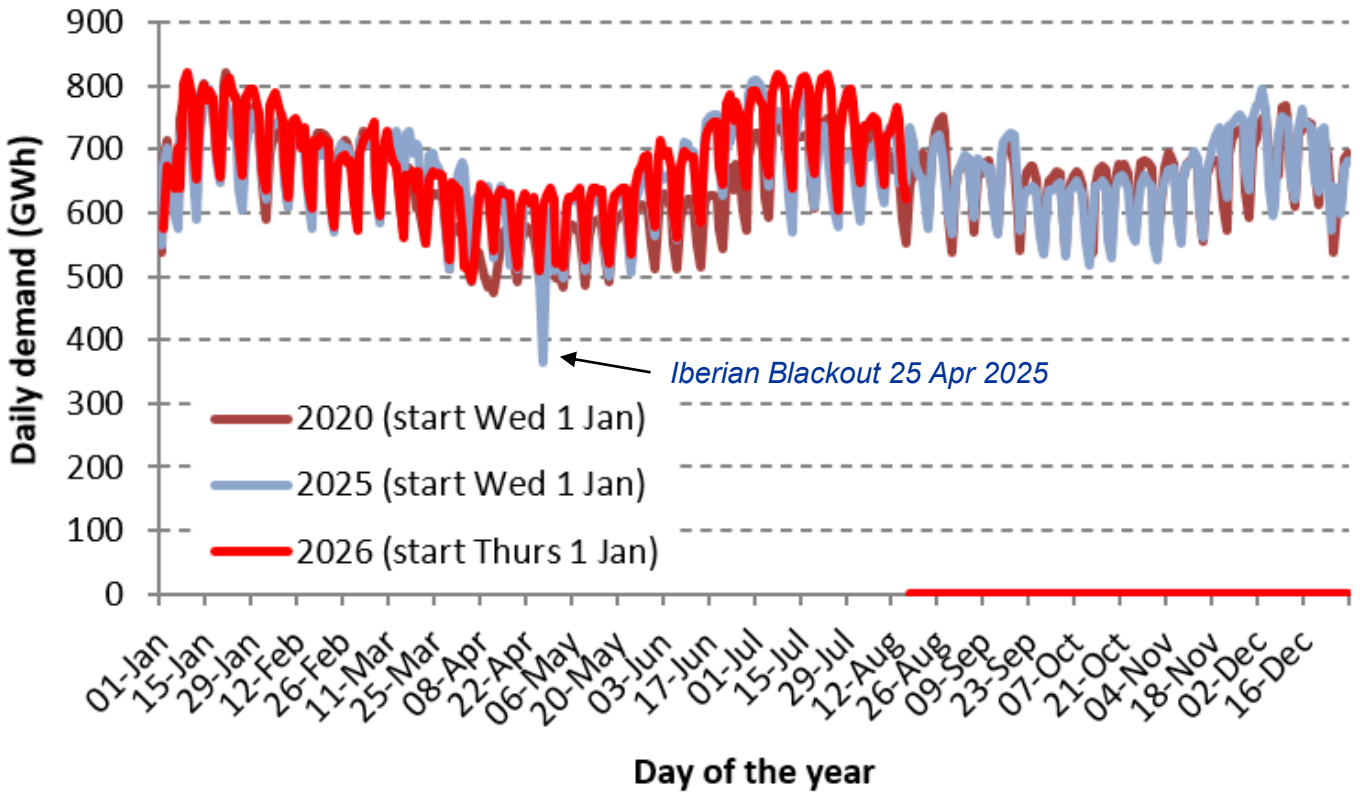
Evolution of demand in 2026

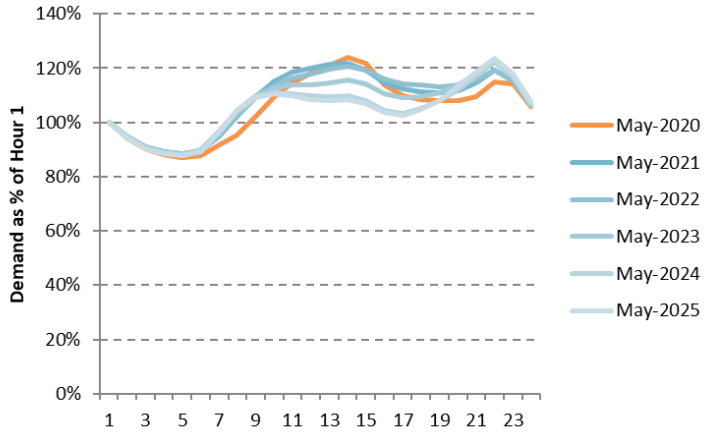
- The chart below shows REE daily demand (synched by weekday) for mainland Spain in 2020, 2025 and 2026 until 16 August. Mainland demand in 2024 was similar to that in 2020 but things have started to change. In 2025, demand was 3.06% above that in 2020 whilst demand in the first 227 days of 2026 has been 2.79% higher than the same period in 2025.

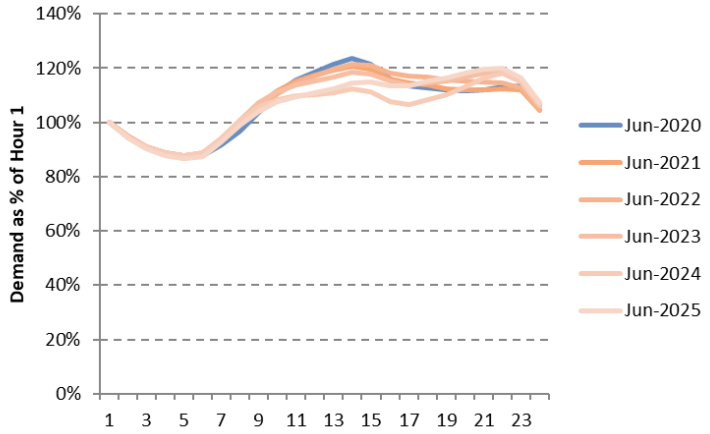


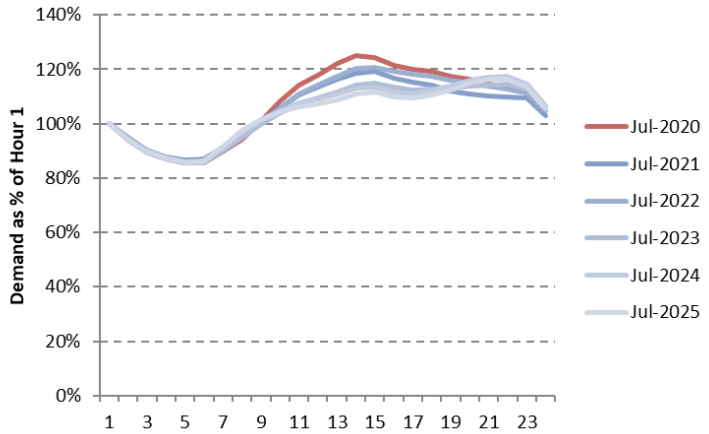
Source: REE and K4K calcs.

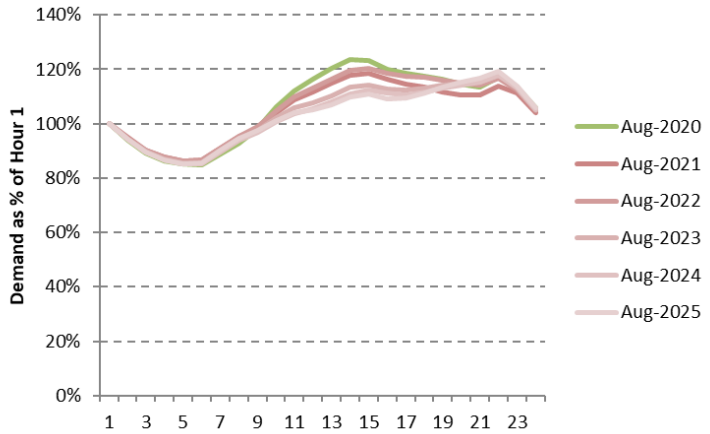
Changing load profile over time

- 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.

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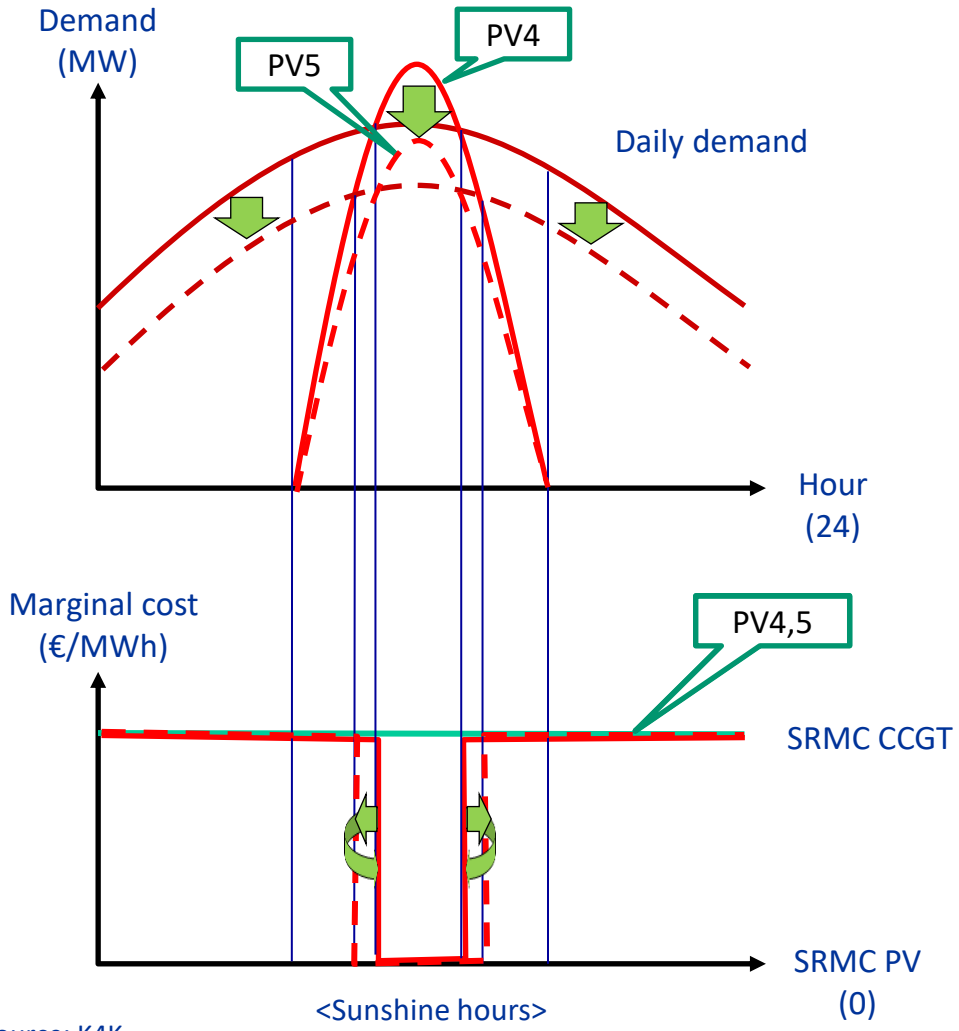
What happens when demand falls?



Source: K4K.

- 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!

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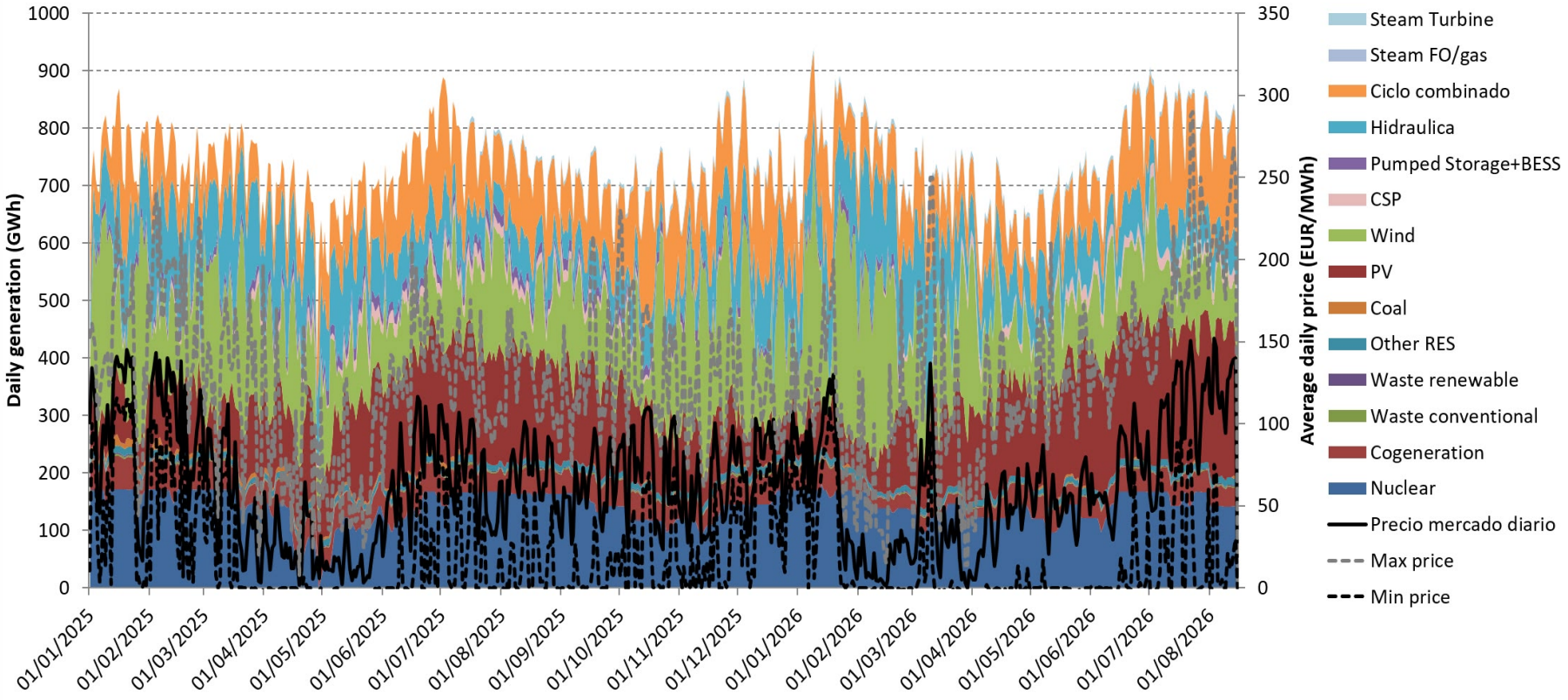
Evolution of generation and prices (1)

- Daily dispatch by technology and average daily spot prices for Spain in 2025-2026. 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.

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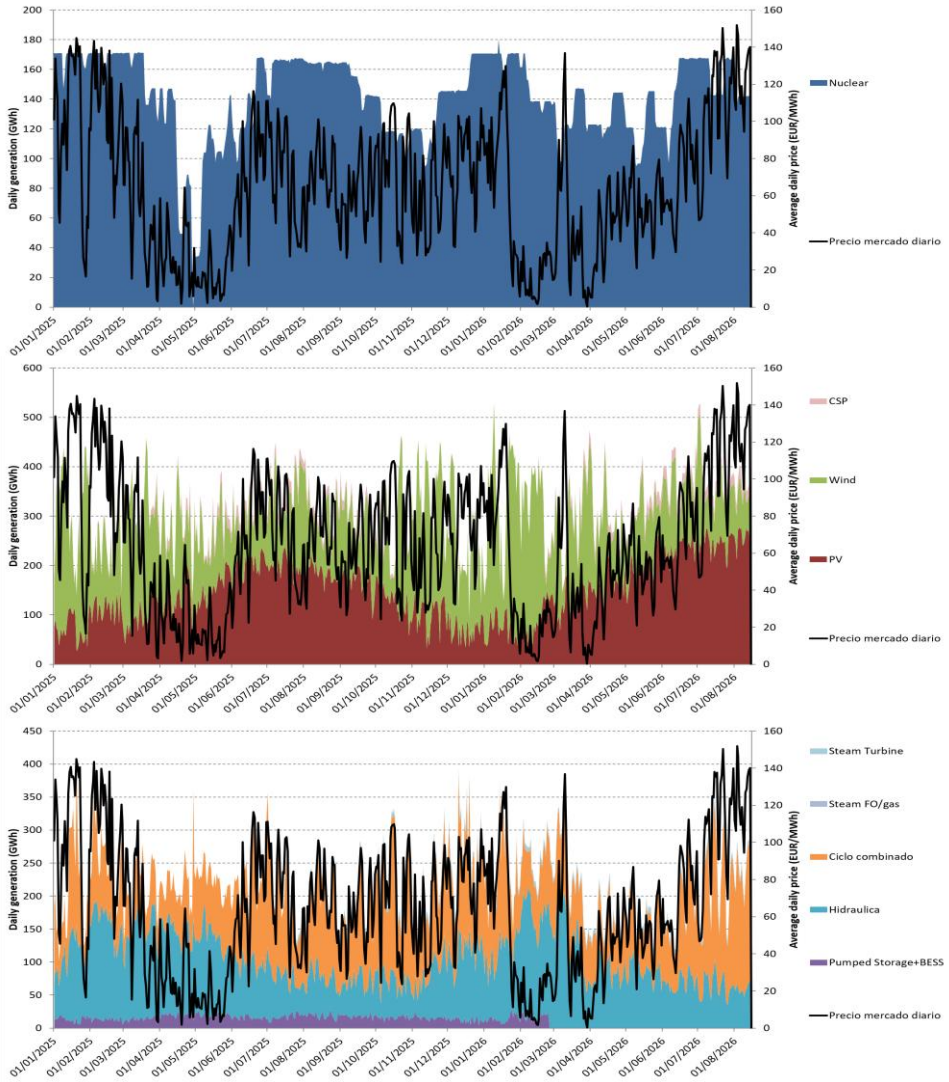
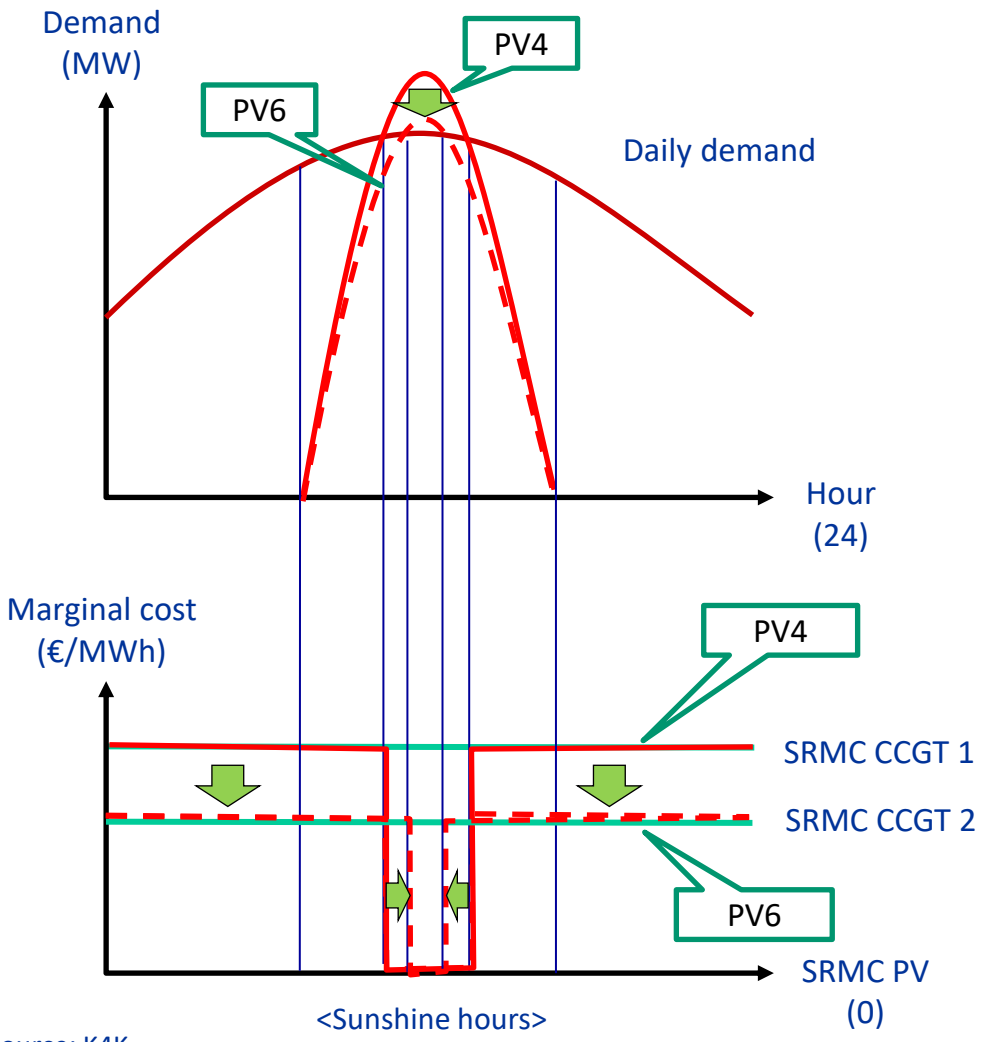
Evolution of generation and prices (2)



- 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 * gas price (€/MWh(f)) before June 2022.
- Flexible hydro tends to shadow the price of the next most expensive flexible technology, i.e. CCGT, so flexible hydro and CCGT dispatch are both 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?



Source: K4K.

- 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.
- New PV cannot support the same number of very low-price hours, so PV penetration must fall to prevent the realised PV price from dropping below 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. This means the market can absorb less PV than before!
- Do we need to reassess 2030 targets and levels of support?

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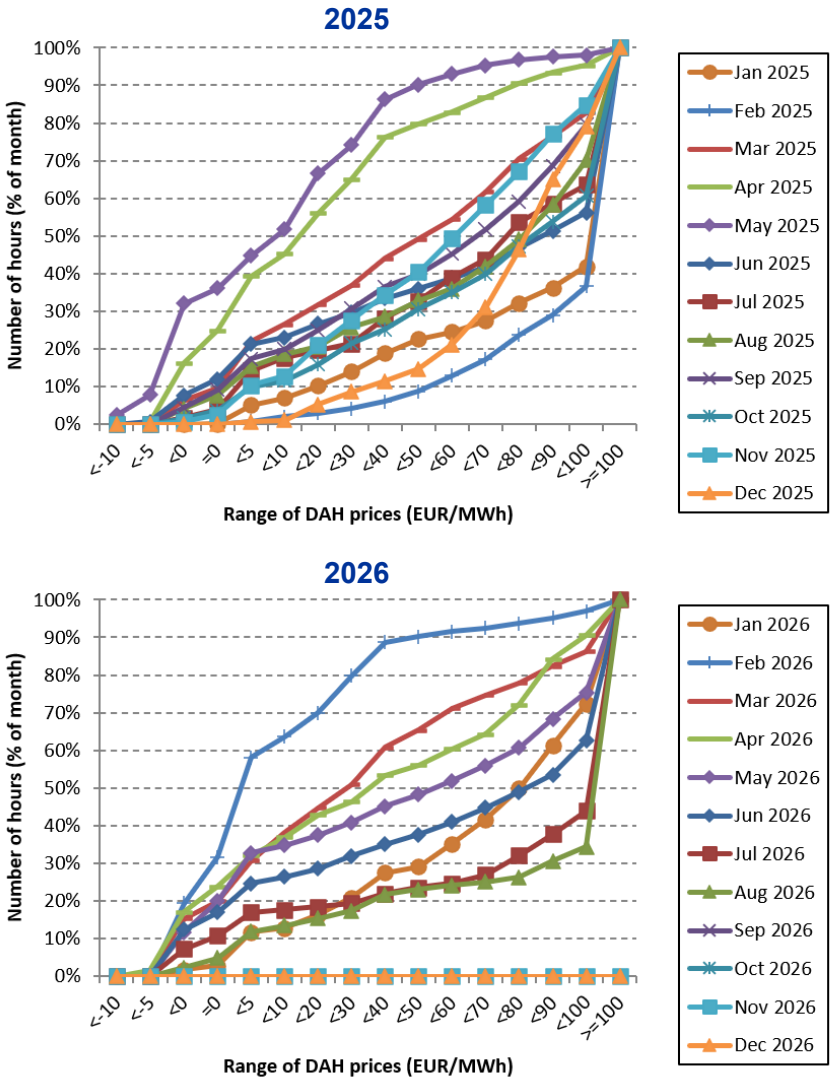
Distribution of hourly DAH pricing continues to evolve



- As intermittent renewables play a more important role, market prices have dropped with a noticeable increase in the number of low-price hours.
- Prices below EUR5/MWh accounted for 18.7% of all hours in 2024, 16.8% in 2025, and 27.9% in 2026 (up to 17 August).
- In contrast to other European markets, negative prices are uncommon, probably because of greater flexibility in the power system, the peculiarities of the Specific Regime to support historical renewables, and the increasing use of exemption clause in PPAs that will not clear if prices are zero or negative.

Source: ENTSO-E, K4K calcs.

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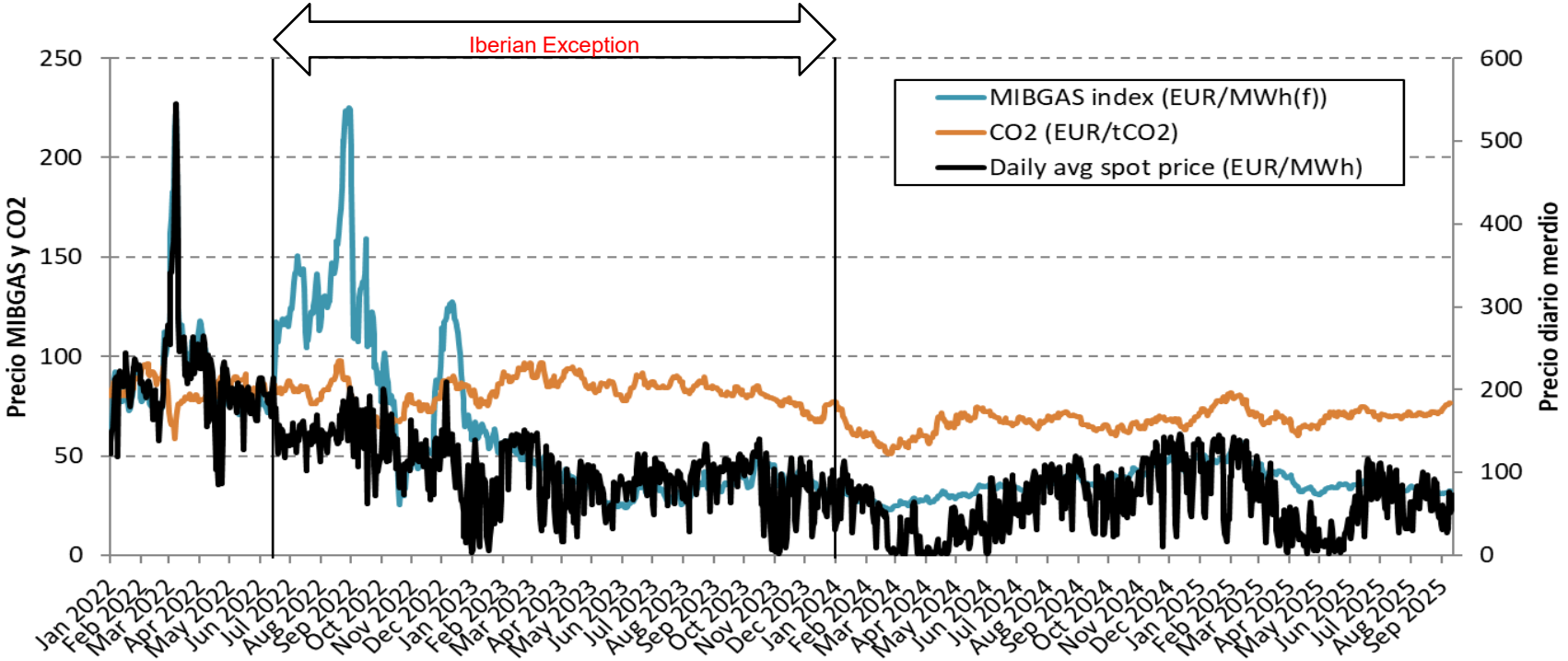
Higher prices can lead to regulatory intervention

- Spanish government responded to high wholesale prices by implementing a 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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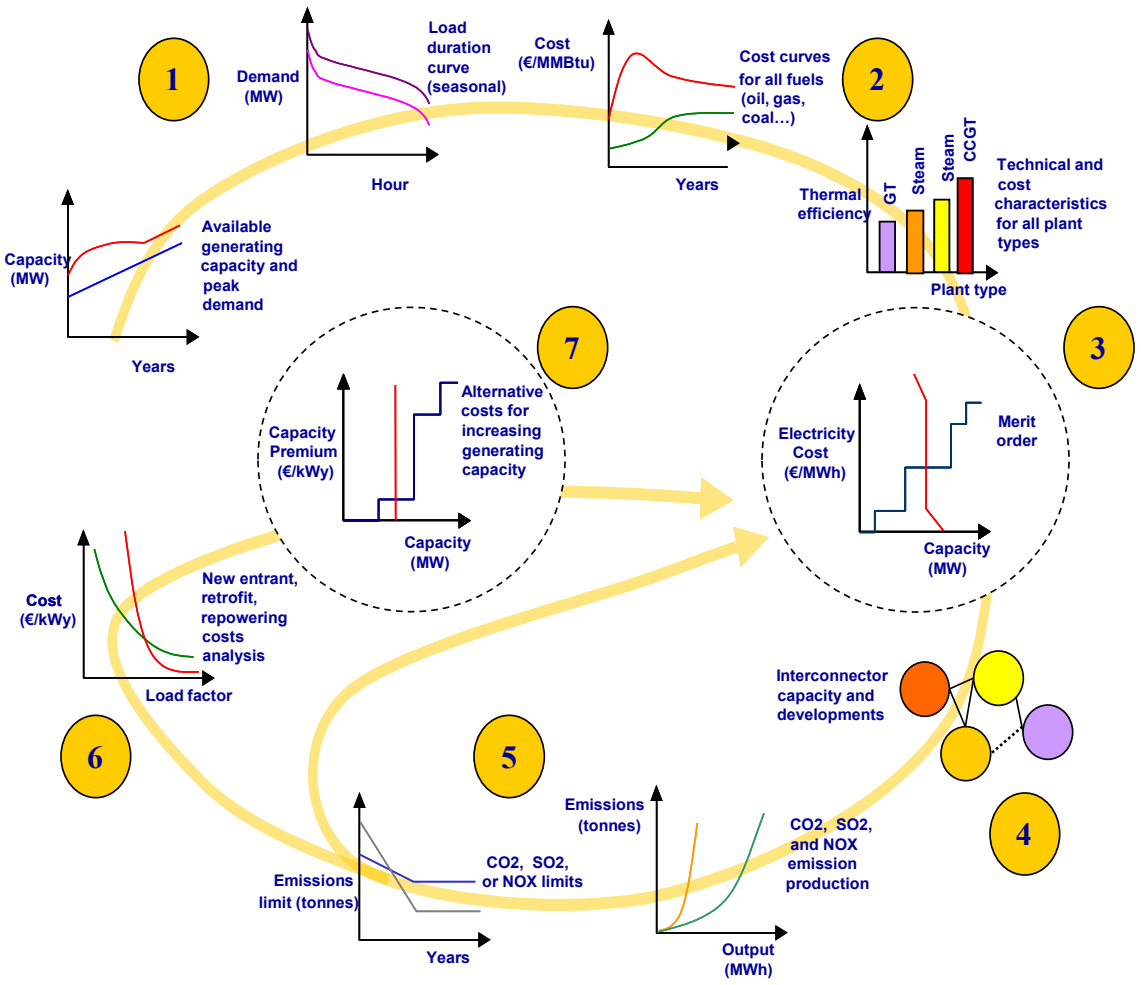
PMM in a nutshell

- PMM (Power Market Model) is designed to replicate the operation of the actual power system being analysed.
- By incorporating the economic, environmental and operational constraints faced by market participants, PMM replicates how stakeholders make decisions in the real world.
- And everything in MS EXCEL.



Overview of Sensitivities

	Low Case *(Low1_20260814)*	Central Case *(Ref1_20260814)*	High Case *(High1_20260814)*
Fuel prices	Gas price cap, MIBGAS/TTF until 2028, CME futures	MIBGAS/TTF until 2028, CME futures	MIBGAS/TTF until 2028, CME futures
CO2 (EUA prices)	ICE futures	ICE futures	IEA WEO 2025 Announced Pledges
Domestic coal surcharge	None	None	Applied
IED coal output cap	None	None	Annual output caps applied
Generation Tax	7.0% in '25, 3.5% in '26 only	7.0% in '25, 3.5% in '26 only	7.0% in '25, 3.5% in '26 only
Demand growth	2.50%	2.0%	2.0%
Green Cent Tax	None	Applied to Coal	Applied to Coal
Annual hours for New PV	1996	1562	1476
Annual hours for New Wind	2494	1952	1844
TIC of New Wind , PV and Battery (€/kW)	-20%	900/650/650	900/650/650
Annual cap on economic New Wind/PV	3/6GW from 2026, uncapped from 2031	3.0/5.0GW from 2026	3.0/5.0GW from 2026

Most important

- Brent, coal and CO2 prices based on CME and ICE futures. Gas indexed to oil from 2029 but linked to MIBGAS in 2026-2027 and TTF in 2028. RDL 10/2022 gas-indexed subsidy extended in Low Case although low gas prices mean no impact.
- High Case applies coal transportation surcharge for domestic coal and a more restrictive view of Industrial Emissions Directive ("IED").
- Timeline for removal of generation already announced.
- "Firm" additions in 2026 of 10GW New PV and 750MW New Wind in all cases. Apply annual caps on the deployment of other "economic" New Wind and PV until 2030 and uncapped thereafter in the Low Case but caps fixed in other cases. 3GW cap on New Battery until 2031 and uncapped thereafter in Low Case, but caps fixed in other cases.

Note: Prices real 2026€.

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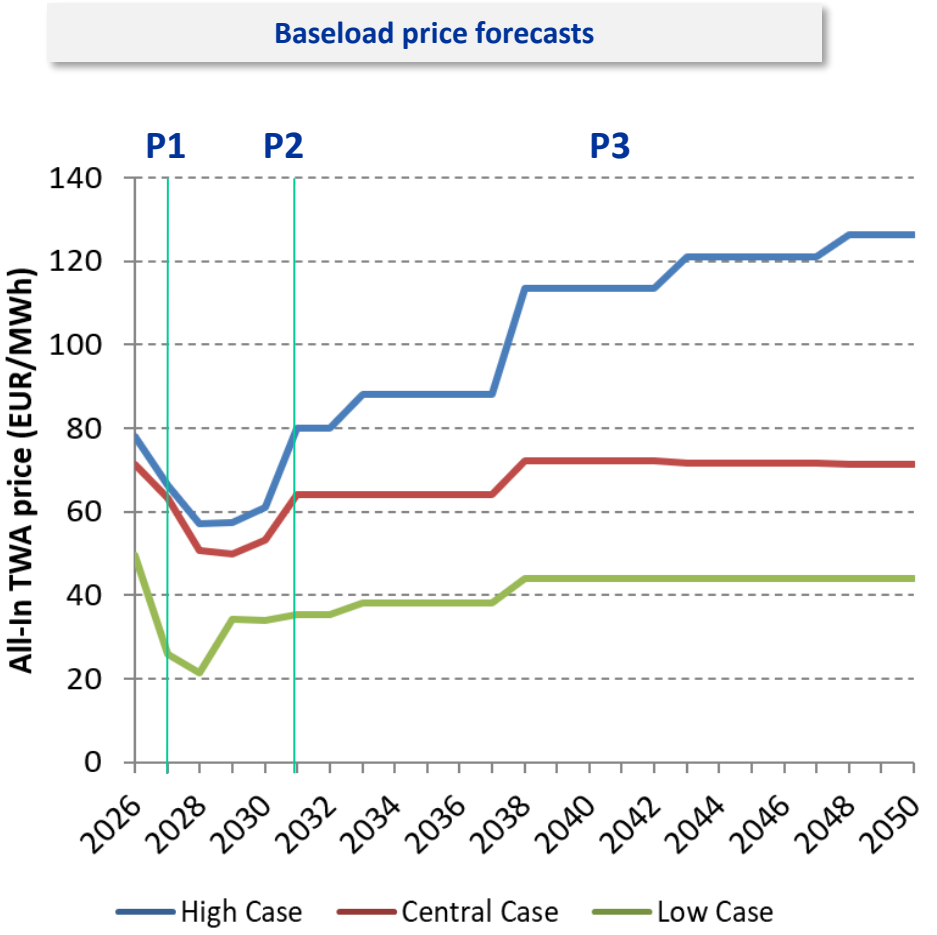
Market price forecasts



- Prices first adjust to reflect aggressive expansion of renewables capacity, especially New PV (P1), and then plateau (P2).
- As a lot of thermal capacity retires in the 2030s, a step-up in prices can be expected especially in the Central and High Cases (P3).
- But even in these cases, renewable capacity eventually catches up and prices hold.

Source: K4K 2026Q3. Prices real 2026€.

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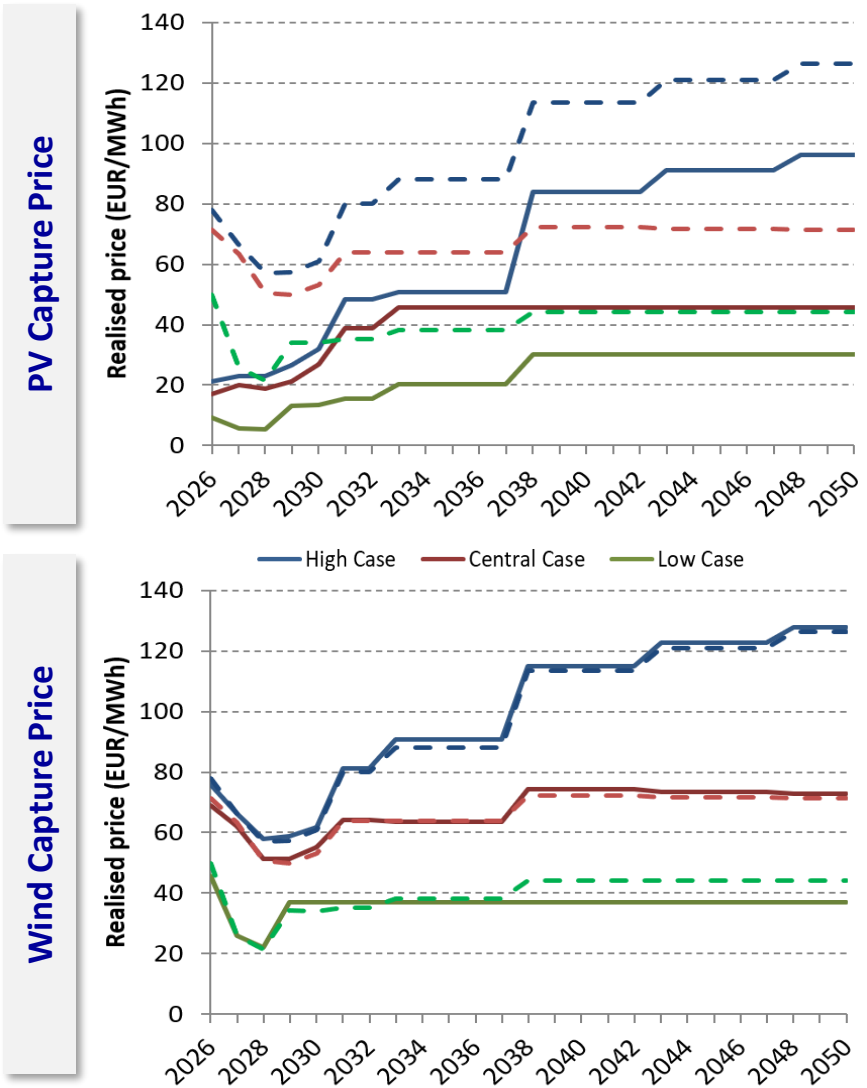
Realised price forecasts

- 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 slowdown in the deployment of New PV leads to price recovery from 2029.
- K4K remains optimistic that profitability of renewables will eventually improve. 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.



Source: K4K 2026Q3. Prices real 2026€. Dashed line = Baseload prices.

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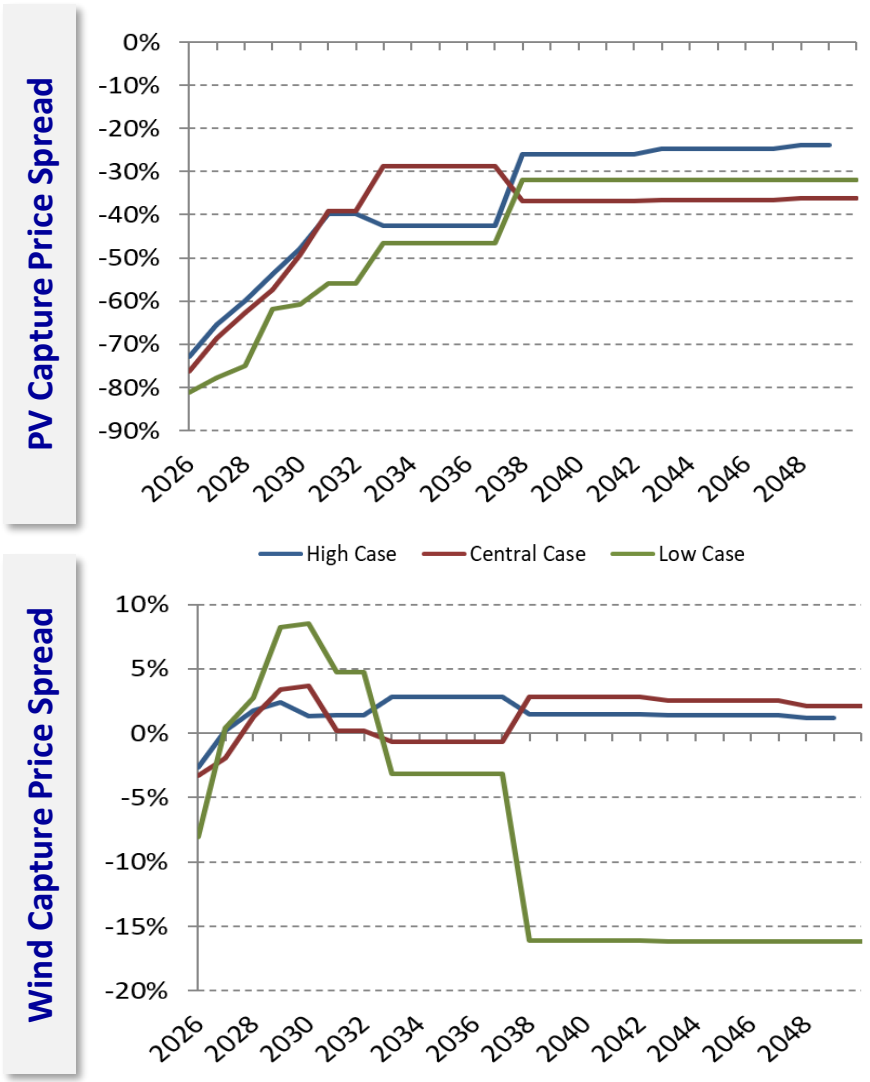
PV and Wind capture price spreads

- 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 = ~(LCOE PV – LCOE Wind) / LCOE Wind



Source: K4K 2026Q3.

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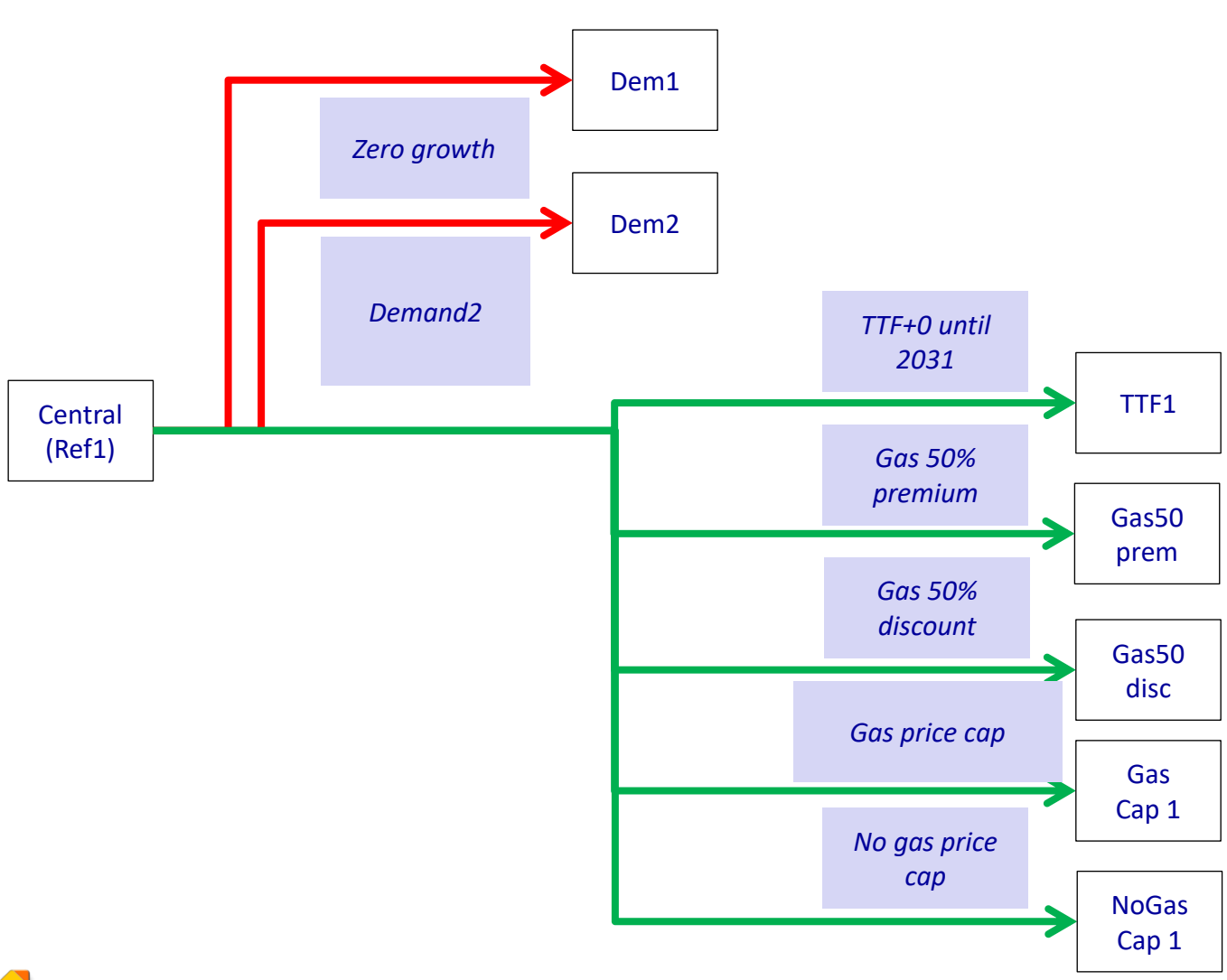
Using the PMM to test different hypotheses

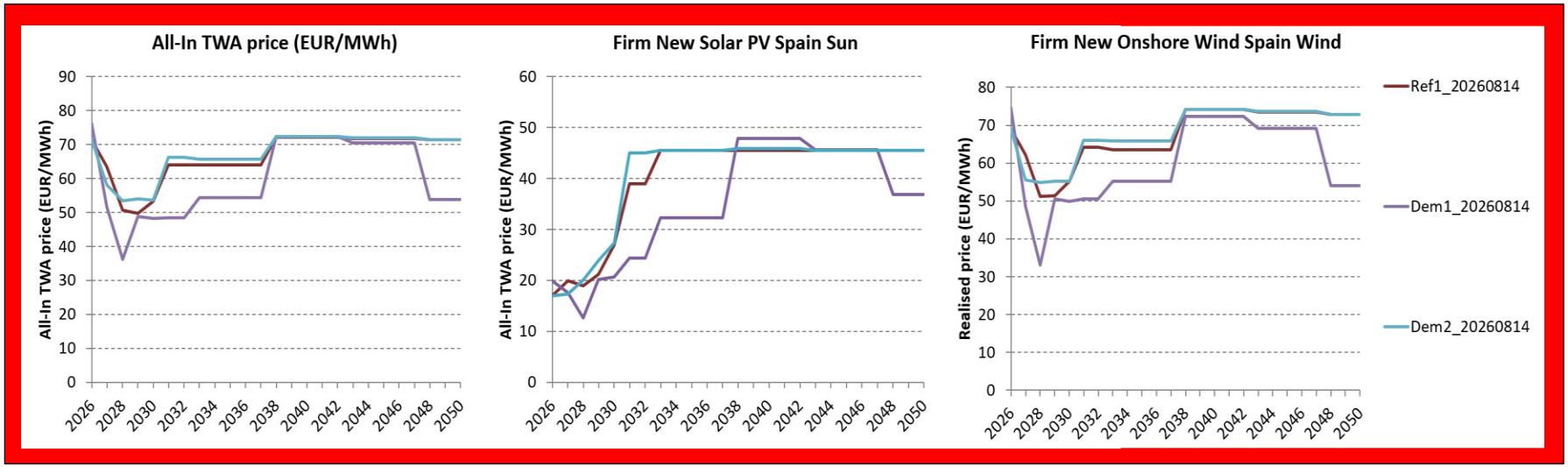
- This exercise raised a number of questions, so we ran path-specific sensitivities to explore the factors that could have the greatest impact on market and realised prices. This was done by defining a series of changes - shown below - and applying them cumulatively to the Central and Low Cases. We also defined two Combined Cases.

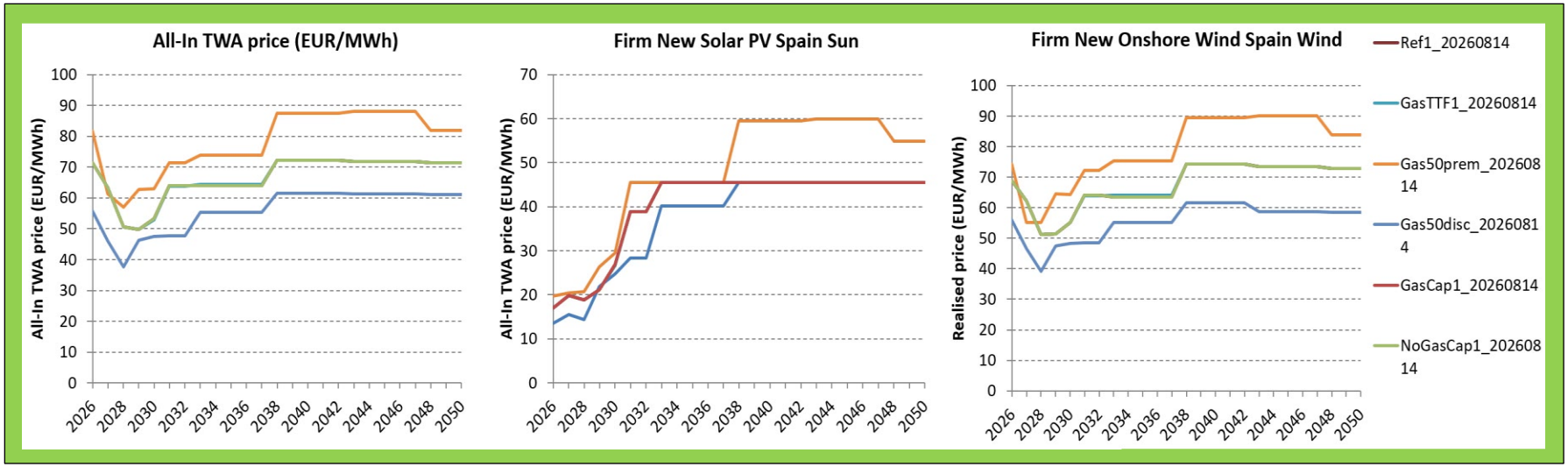
Change applied	Explanation
Demand1	Demand as in Low1.
Demand2	2.5% growth 2026-2035 and 2.0% thereafter, reaching 1.5x CC demand by 2050.
Zero growth	Zero demand growth.
Firm New Build 1	Add 1.5/2.0GW annually until 2030 of Firm New Wind/PV (additional to Economic New Build limits).
Firm New Build 2	Add 1.5/7.0GW annually until 2027 of Firm New Wind/PV (additional to Economic New Build limits).
Uncap from 2026	Uncap Economic New Builds from 2026 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 2026-2050: New Wind=882 to 652, New PV and New Battery =624 to 340.
No RES closure	No retirement of existing RES (or cogeneration).
Endogenous closure	Allow the model to retire coal, CCGT and nuclear capacity on economic grounds.
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)



Sensitivity results (path 1-2)





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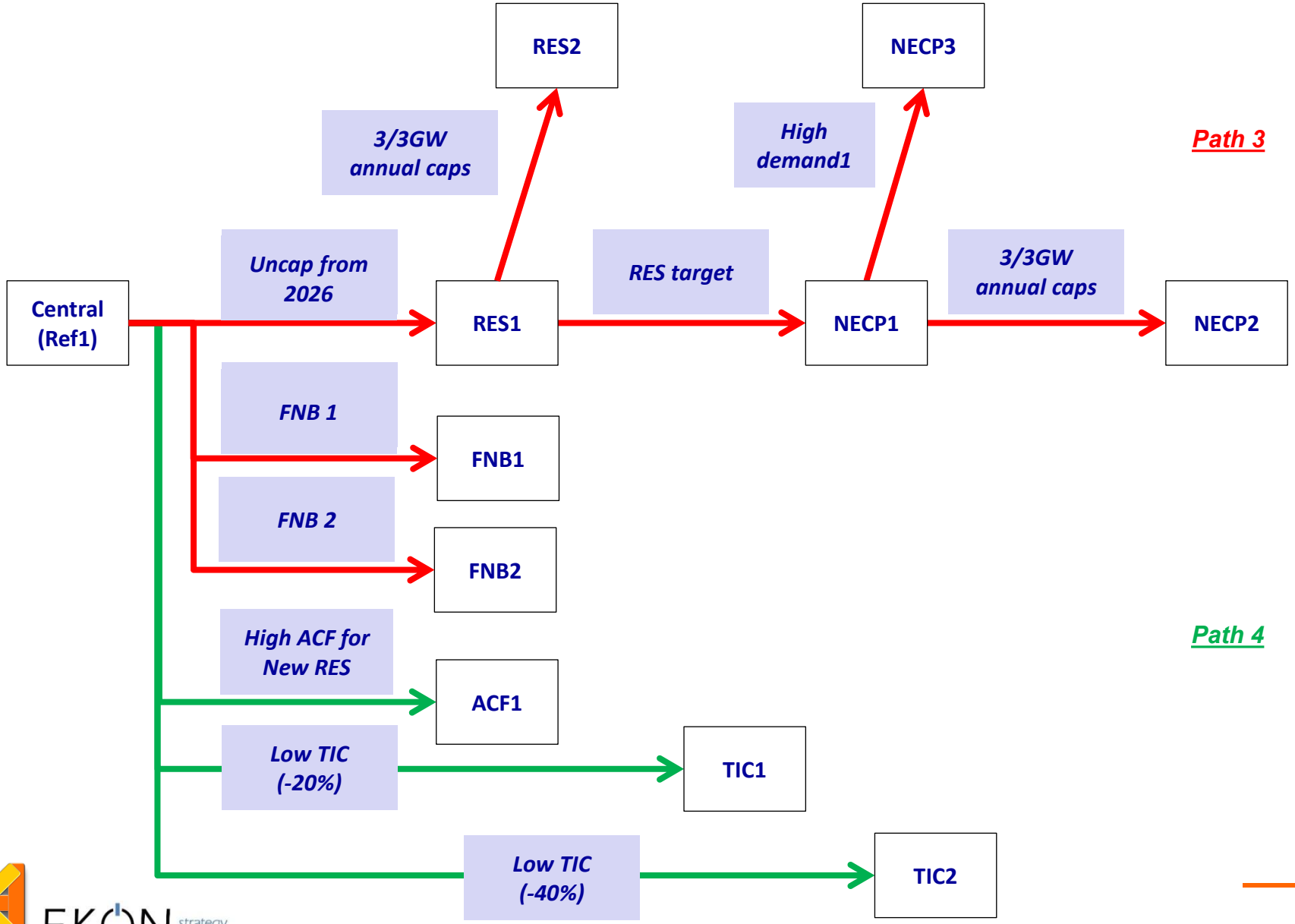
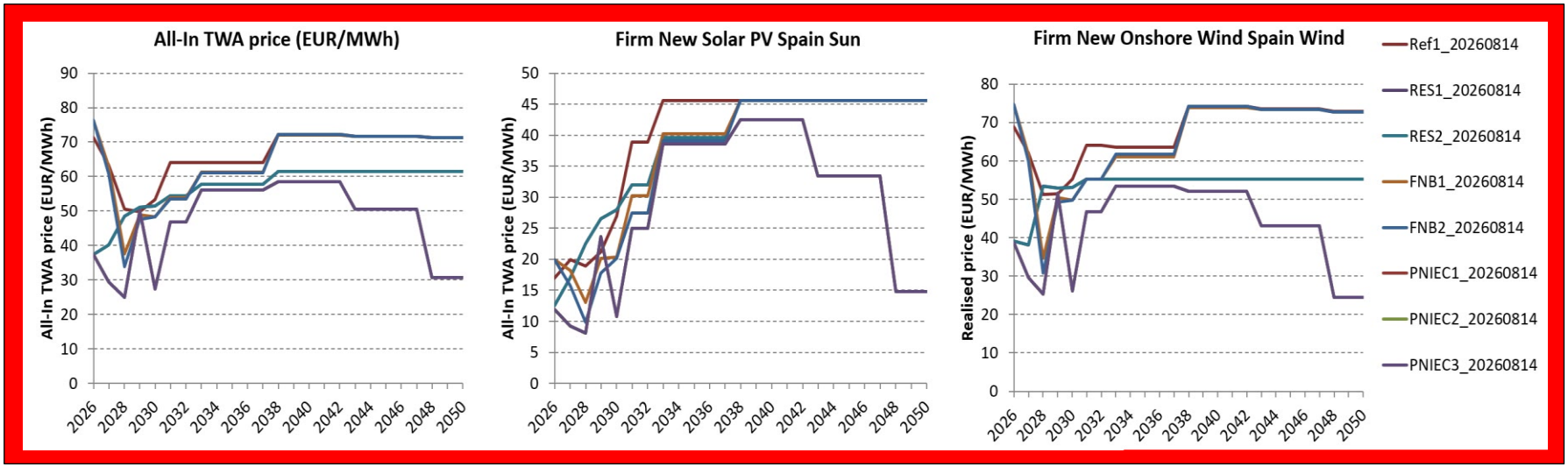
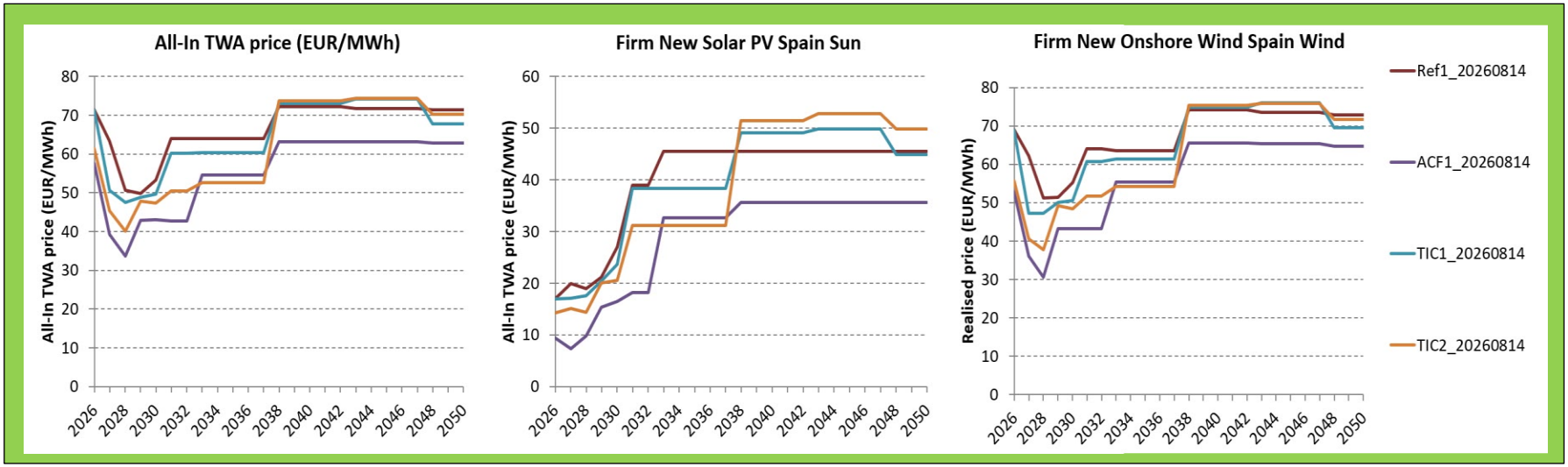
Defining modelling paths (3-4)



Sensitivity results (path 3-4)





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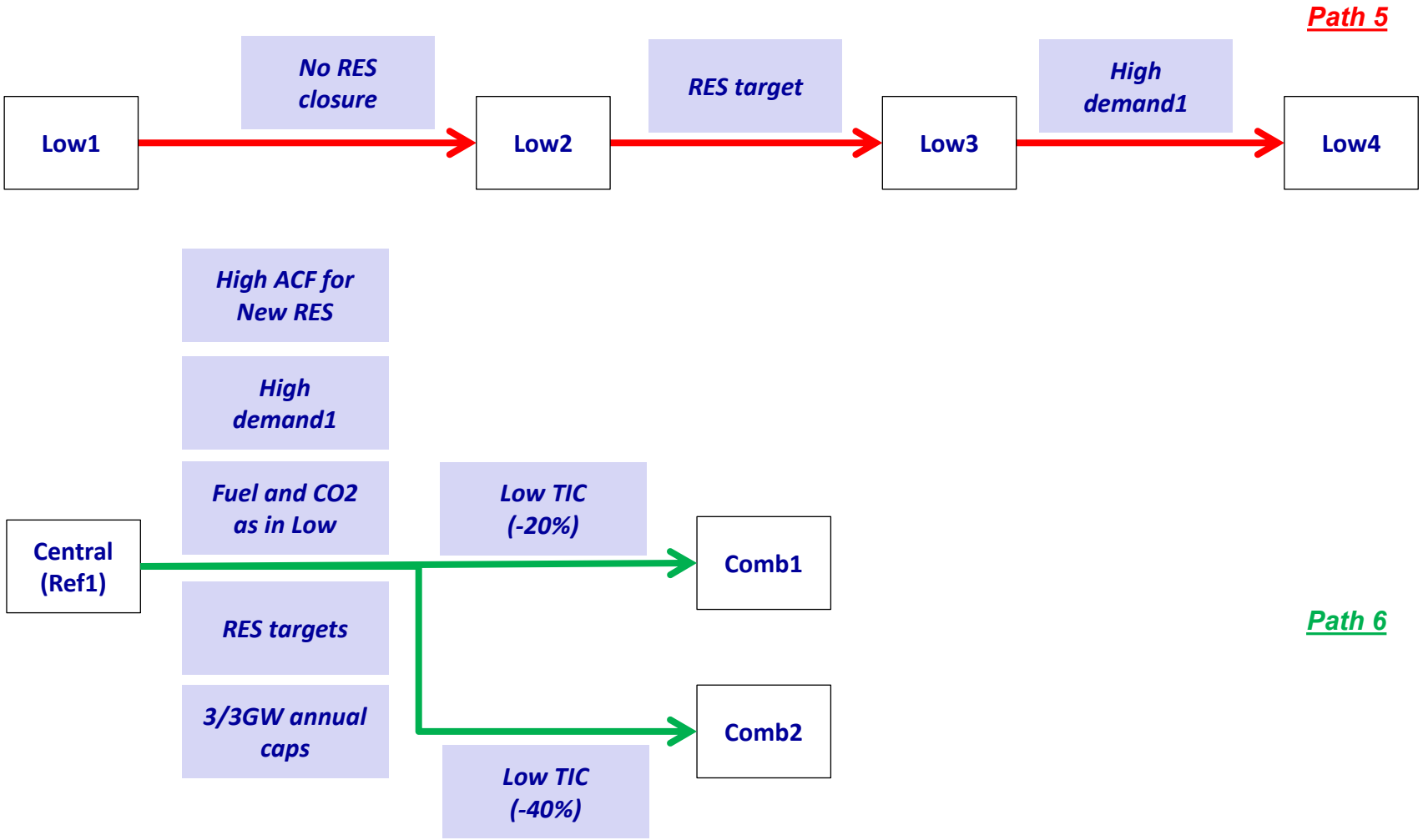
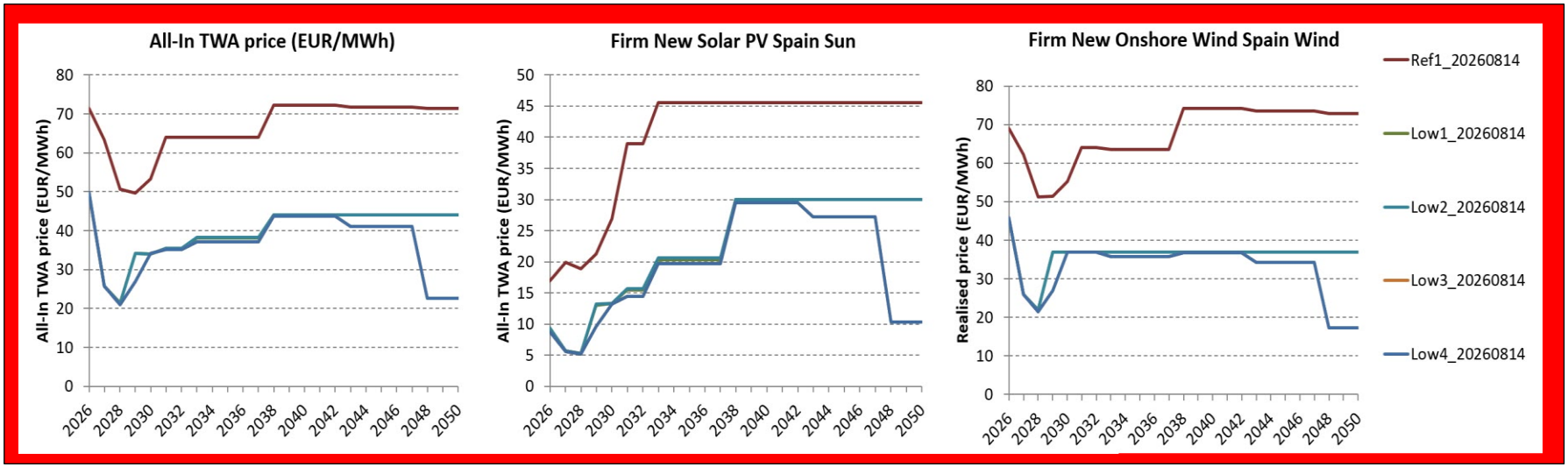
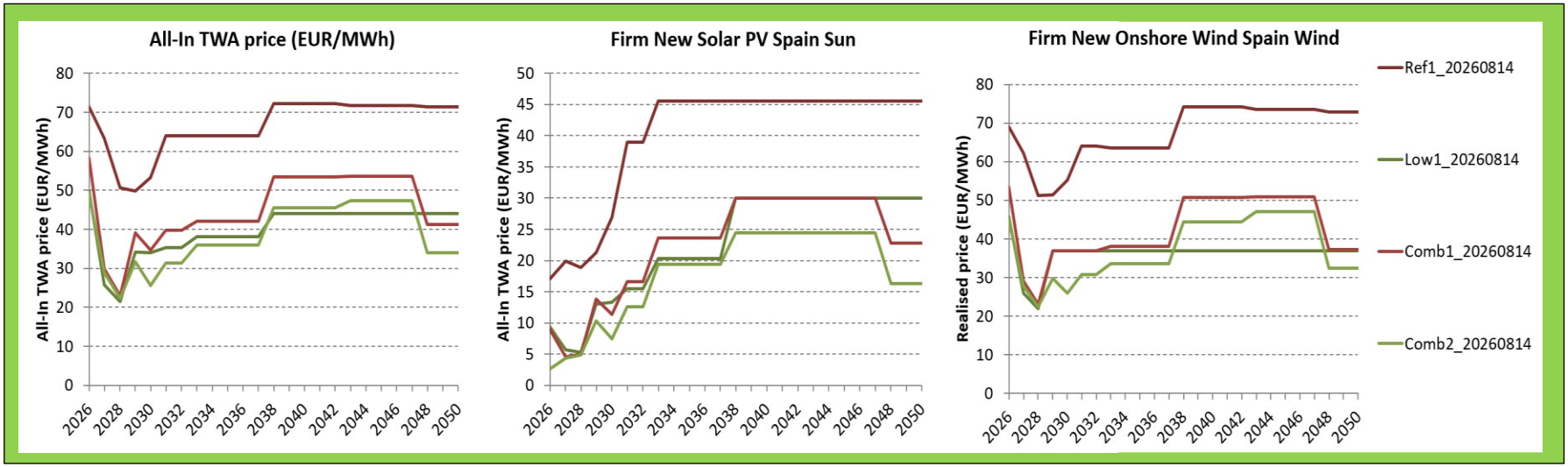
Defining modelling paths (5-6)



Sensitivity results (path 5-6)





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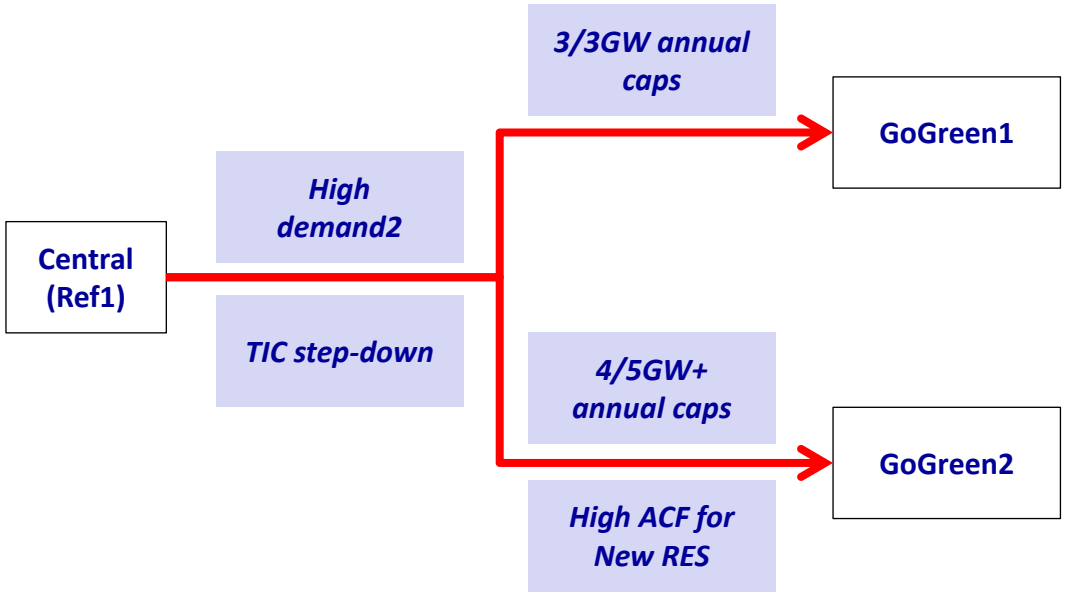
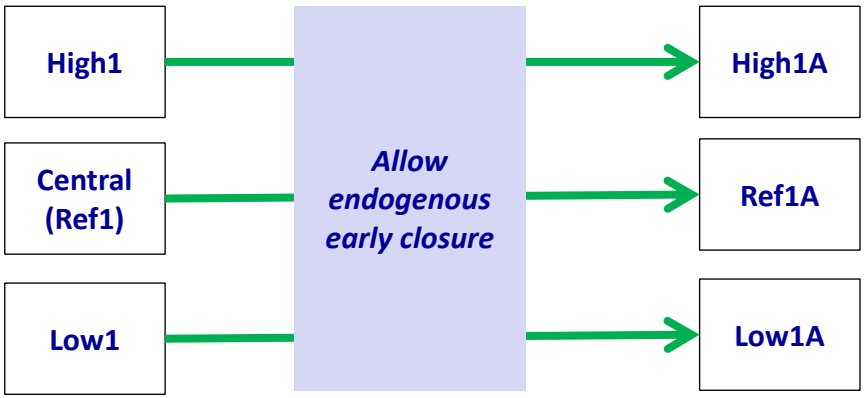
Defining modelling paths (7-8)

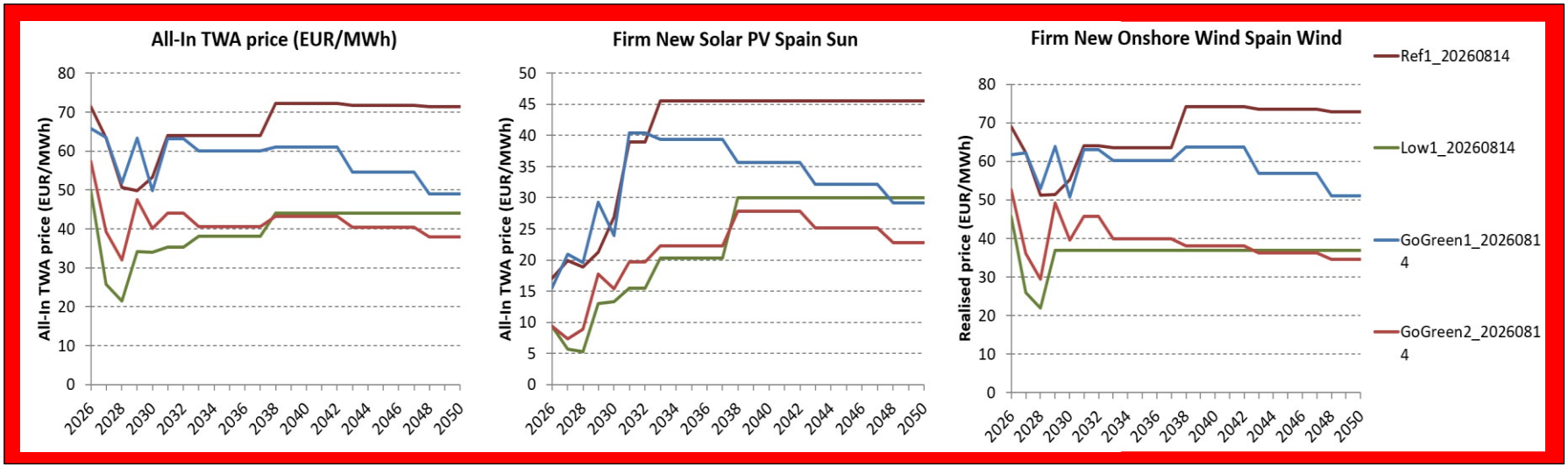


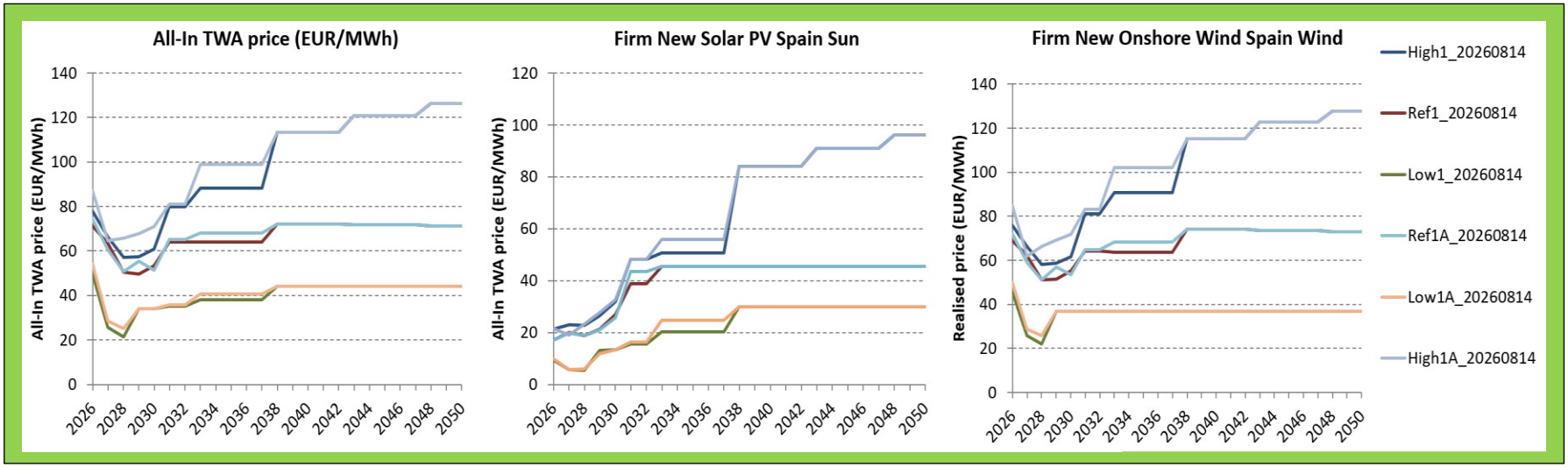
Path 7



Path 8

Sensitivity results (path 7-8)





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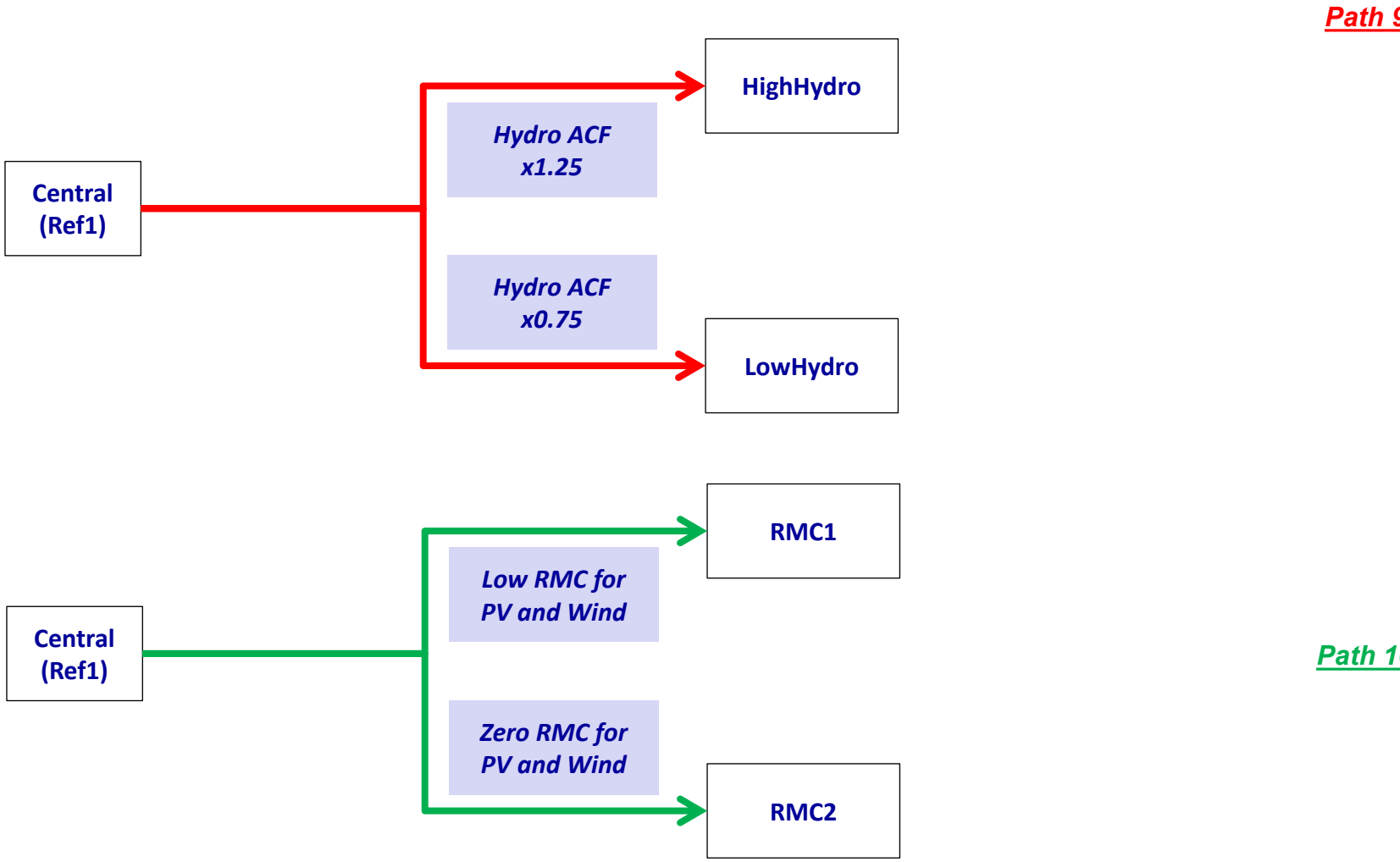
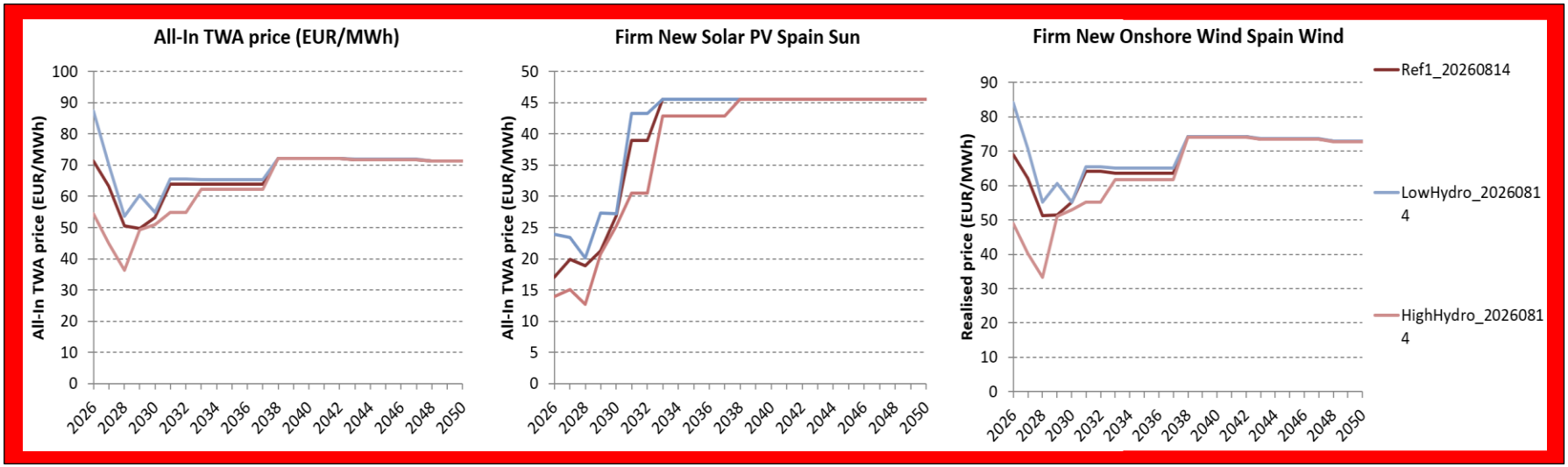
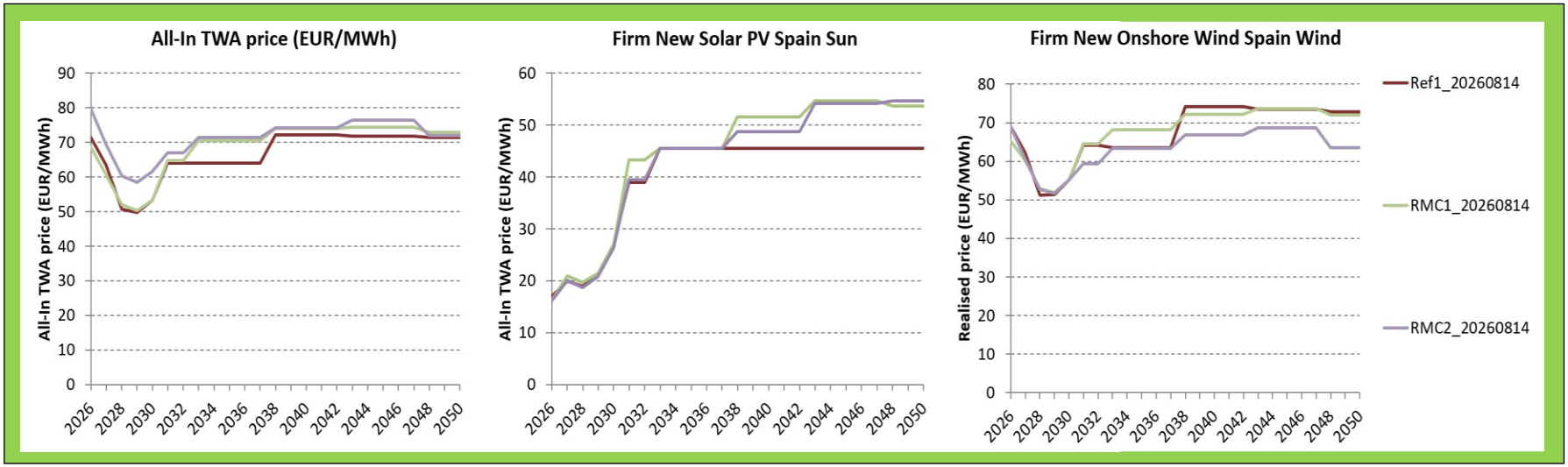
Defining modelling paths (9-10)



Sensitivity results (path 9-10)





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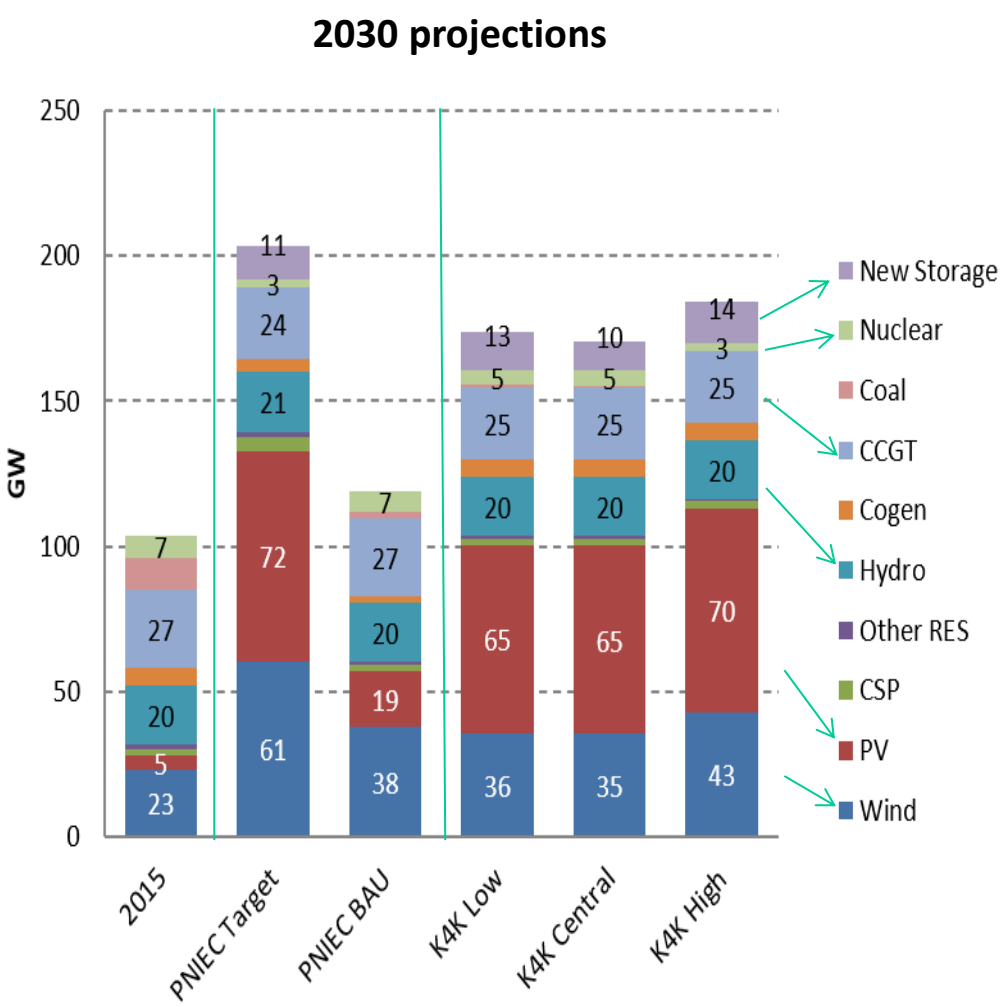
Achieving the NECP 2030 targets

- Share of renewable generation in K4K Central Case is 75.98% and 84.94% in the Low Case (compared to 81% target in updated NECP).
- NECP capacity targets are very aggressive since they require a 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 the merchant market and be open to legal challenge for discrimination.
  - Better to use a 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: National Energy and Climate Plan 2023-2030 ("NECP") 2024, Mainland figures only, K4K 2026Q3.

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And beware NECP assumptions

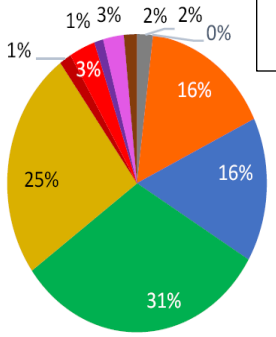
Figura D.7. Resultados Escenario Objetivo H2030

Escenario Objetivo H2030. Plan de Energía y Cambio Climático.

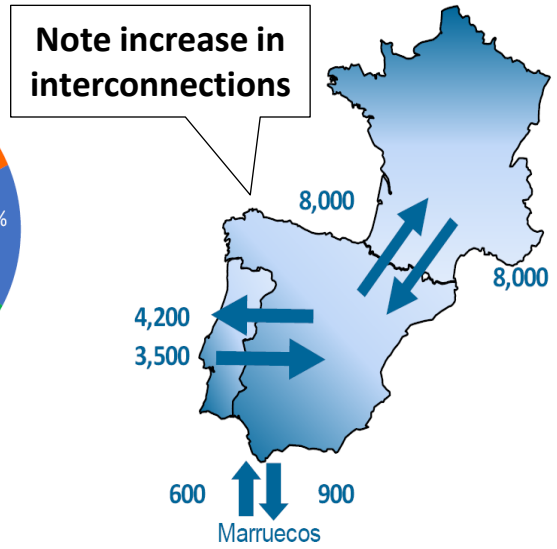
España Peninsular		Generacion mínima síncrona:	3N+7 Térmicas	*Cod 01_2030*
La demanda en ES (TWh):	263	Demanda punta (MW):	47,768	

Capacidad instalada en España (MW)

	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%**



Capacidad de intercambio (MW)



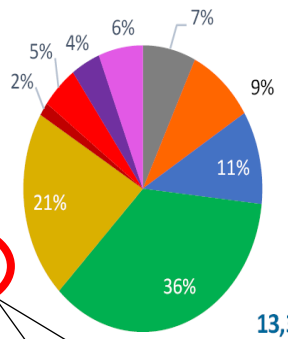
Source: NECP (Jan 2020) Annex D.

Capacity may not need to be that high

Balance de generación (GWh). España peninsular

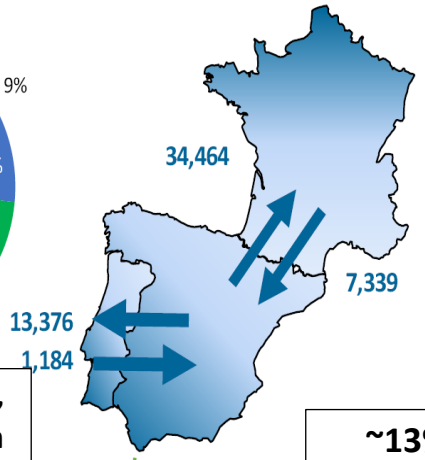
	GWh	%	Horas utilización
Nuclear	22,034	7%	7,224
Carbón	0	0%	0
Ciclos	27,617	9%	1,124
Hidráulica	32,376	11%	1,341
Eólica	109,464	36%	2,255
Solar FV	65,180	21%	1,697
Termosolar	4,629	2%	2,013
Termosolar almacen. 9h	15,156	5%	3,031
Resto RES	12,088	4%	6,987
Cogeneración y otros	18,399	6%	4,623
Generación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

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



Historical wind, but PV too high

Saldo de intercambios anual (GWh)



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

~13% of generation for export?

Source: NECP (Jan 2020) Annex D.

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Draft NECP even more unlikely

Escenario Objetivo H2030. Plan de Energía y Cambio Climático.

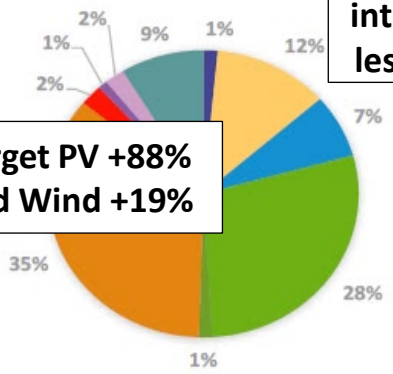
España Peninsular	*Generacion mínima síncrona:*	7 CC + 3 NUC	*Cod 2030_600*
Demanda (TWh):	**344.0**		
Punta horaria de demanda (MW):	**53794**		

+31% and +13% respectively

Capacidad instalada (MW)

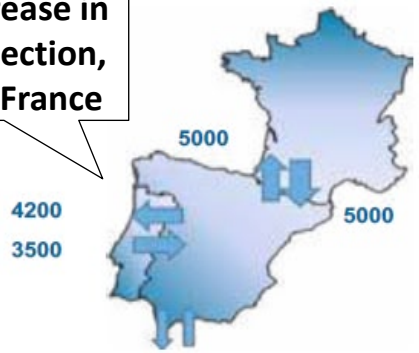
	MW	%
Nuclear	3041	1%
Carbón	0	0%
Ciclos	24499	12%
Hidráulica (sin bombeo)	14562	7%
Eólica terrestre	57737	28%
Eólica offshore	2800	1%
Solar FV	72130	35%
Termosolar	4804	2%
Resto RES	1964	1%
Cogeneración y otros	4205	2%
Almacenamiento	17612	9%
Total sistema	**203353**	**100%**
Electrolizadores	**11980**	

Target PV +88% and Wind +19%



Capacidad de intercambio (MW)

Same increase in interconnection, less with France



Información adicional:

Potencia renovable en España peninsular (MW)	***153997***	*76%*	*del Total sistema*

Source: Updated NECP (2024) Annex D.

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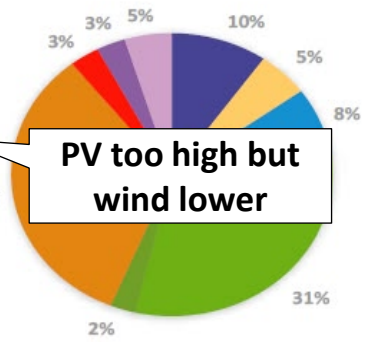
Generation and capacity probably too high

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%**	

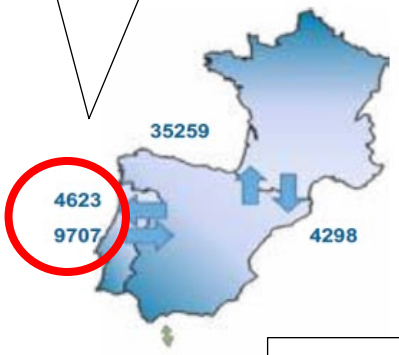
[1] *Sin almacenamiento*

Balance almacenamiento	**-7185**	GWh
Consumo	*35447*	
Producción	*28262*	



PV too high but wind lower

Reversal of flows with PT but FR takes up the slack



Perfil Marruecos

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*

Source: Updated NECP (2024) Annex D.

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Final comments

- What if the government sets capacity targets that exceed market saturation points, as seems likely? Let's hope it does not discriminate between different cohorts of assets! Setting an aggressive green energy target (GWh) and backing it with tradable green certificates would help protect all investors — old and new — from the inevitable erosion of realised electricity prices as deployment is pushed beyond the market saturation point.
- As renewable penetration increases, value progressively shifts from producing more MWh towards providing flexibility to the system.
- So, when forming a view on realised prices for PV or wind, consider:
  - Demand growth ← **Affects saturation point**
  - Fuel prices
  - EUA prices ← **Short-term impact**
  - Taxes (Generation Tax, Green Cent Tax)
  - Lifetime limits for existing plants (including cogeneration and renewables)
  - Hydrology
  - Operating 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 NECP targets (including auctions) ← **Especially important**