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Reaping the benefits of renewable energy.

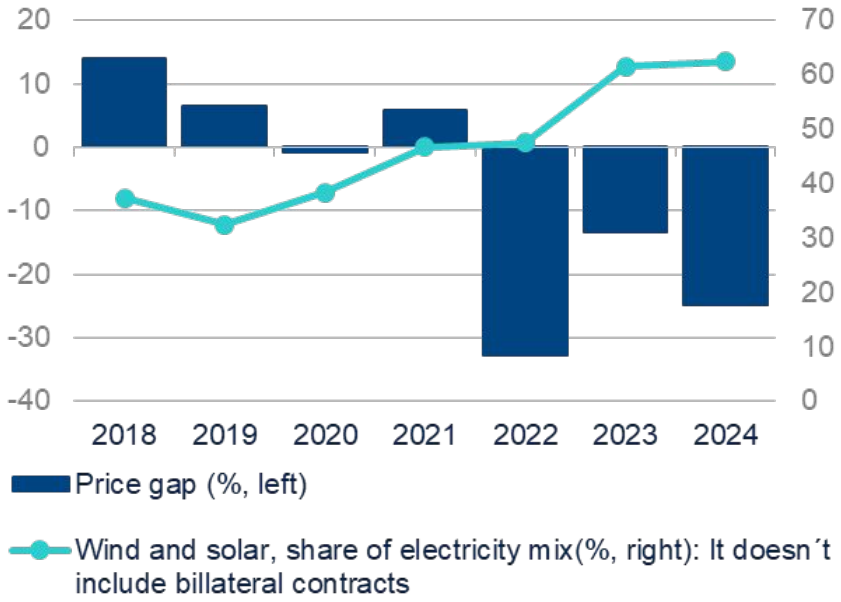
Economic impact of lower cost of energy

14 February 2025

Creating Opportunities

Does the increasing share of renewables contribute to lower electricity prices?

SPAIN. WHOLESALE ELECTRICITY PRICES (*) GAP AND WIND & SOLAR SHARE IN ELECTRICITY MIX
(% WITH EUROPEAN MEDIAN, LEFT; % RIGHT)



(*) These are the prices paid to electricity generators, and are not necessarily the same as the costs to end users.
Source: BBVA Research from European power price tracker | Ember and OMIE.

- The price of the Spanish wholesale electricity market has gone from exceeding the European median between 2018 and 2021 to falling below it since 2022.
- During the same period, the share of renewables (solar and wind) in the daily wholesale market has risen from not exceeding 40% of the total to be around 65%.
- **Does the increasing weight of renewables contribute to lower wholesale electricity prices?**
- **Would the "merit-order effect" hinder the penetration of renewables?**

Key messages

Energy Consumption in Spain

- Spain's energy consumption is dominated by the transport, industry, and residential sectors (around 80%). Transport relies mainly on oil products while other sectors primarily use electricity and natural gas. The reliance on imported gas is significant and concentrated in a few countries.

Spain, a European Leader in Renewables

- Spain is advancing toward greater energy sovereignty through renewables. The rapid growth in renewable installed-capacity has boosted the use of them, accounting for 65% of the electricity mix in mid-2024 (without hydro and bilateral contracts).

Impact of Renewables on Wholesale Electricity Prices

- From 2021 to 2024, the increase in the renewable energy share from 45% to 65% is estimated to have reduced wholesale electricity prices by 20% (12.5% in 2021-2023 and 7.5% in 2024) according to BBVA Research.
- Looking ahead, meeting the PNIEC 2030 target could reduce prices by a further 20%. While plausible, this objective may seem overly optimistic over five years.

"Merit order effect" and Investment in Renewables

- Greater renewable penetration lowers electricity prices through the "merit order effect" (low marginal cost technologies, such as solar and wind, shift the market supply curve to the right and the marginal price declines), impacting their profitability. However, no evidence shows it has deterred renewable investment ("cannibalization").
- Sustaining the growth in renewables will require regulatory advancements and investment to position Spain as a leader in the energy transition, ensuring a more competitive, sustainable and resilient future.

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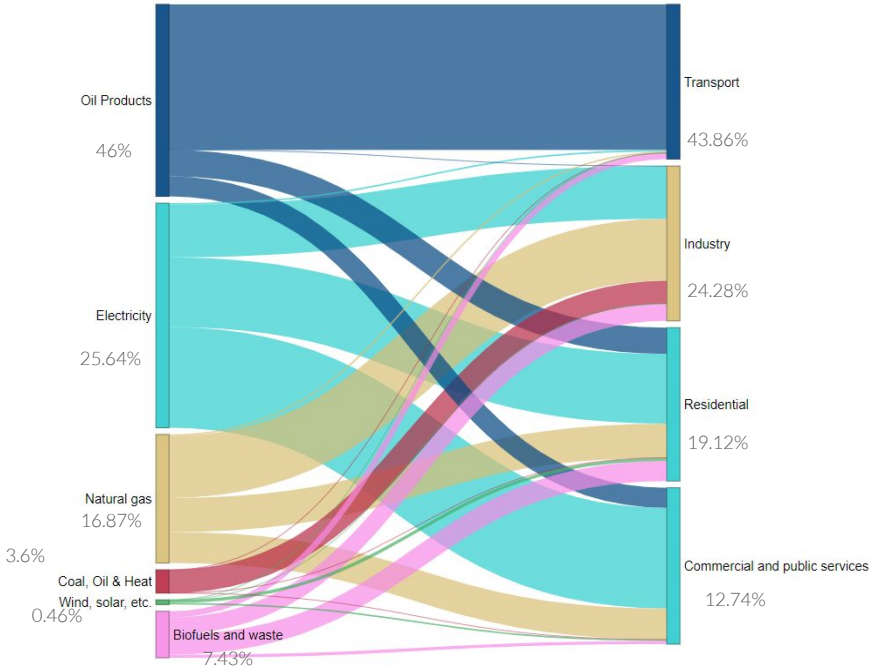
01

Energy consumption in Spain

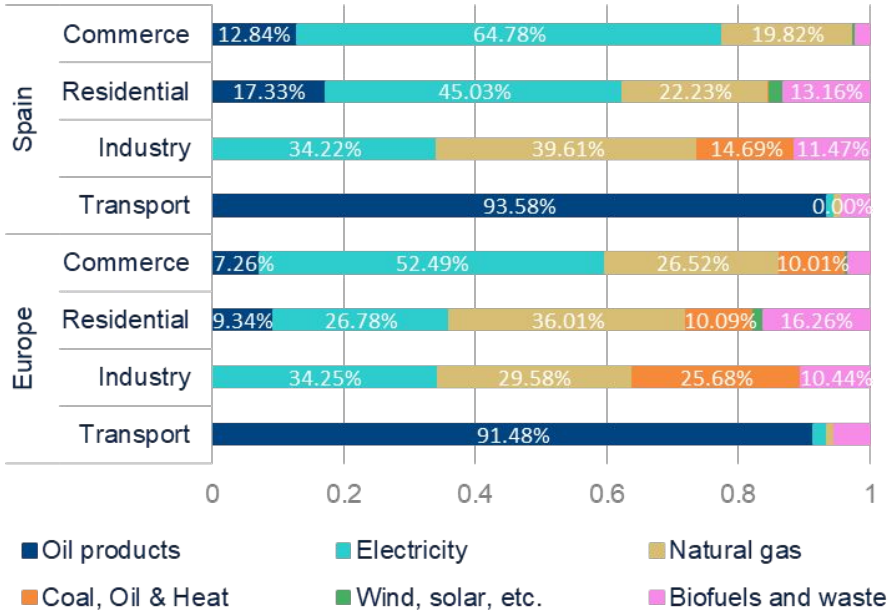
Spain's energy consumption is dominated by transport, industry, and residential (80%), with oil products prevalent in transport and electricity/natural gas in other sectors

SPAIN. TOTAL ENERGY CONSUMPTION (TEC) BY SECTOR AND SOURCE. 2022 (% OF TEC BY SECTOR) (SEE EUROPE)



Source: BBVA Research from IEA data.

TOTAL ENERGY CONSUMPTION (TEC) BY SECTOR AND SOURCE. 2022 (% OF TEC BY SECTOR) (*)

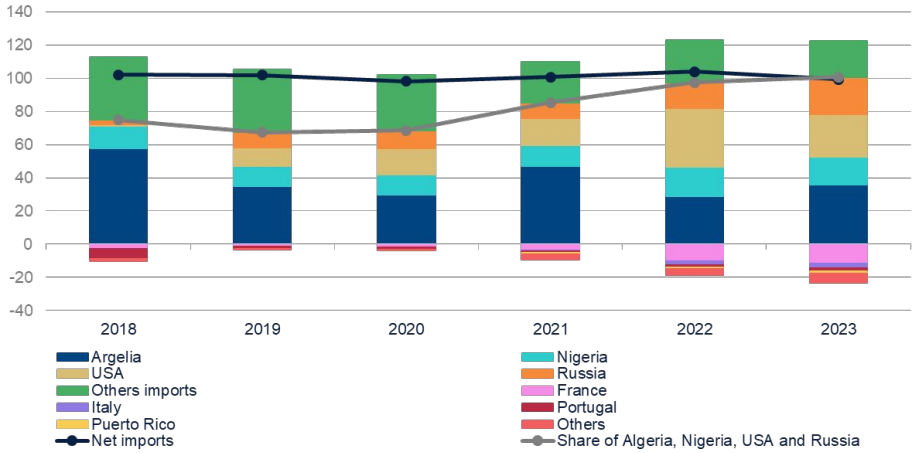


Source: BBVA Research from IEA data. (*) Commerce includes public services.

Spain is highly dependent on oil and gas from a few countries, which poses a risk to energy supply and electricity prices, highly correlated with gas prices

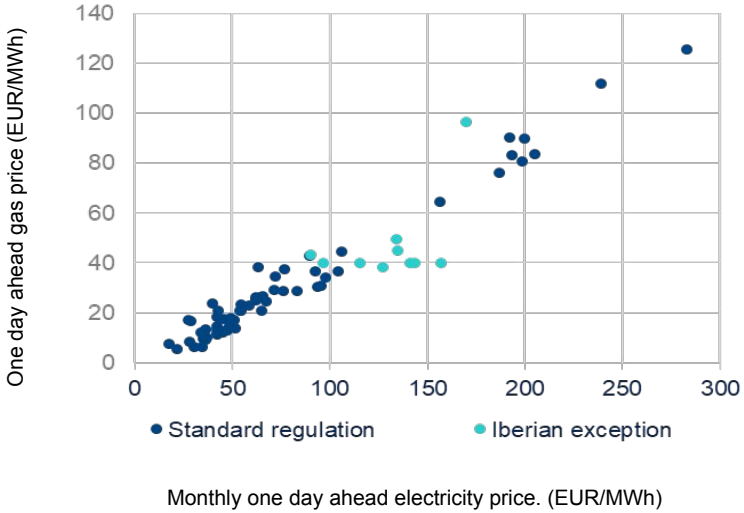
SPAIN. GAS SUPPLY FROM MAIN PARTNERS

(UNIT OF EXPORT OR IMPORT PER UNIT OF GAS CONSUMPTION (%) (*)



WHOLESALE ELECTRICITY AND GAS PRICES

(EUR/MWH. MONTHLY DATA, 2018-2023) (**)



Source: BBVA Research from CORES data. (*) Natural gas consumption includes gas used as feedstock (non-energy use).

Source: BBVA Research from OMIE and MIBGAS data. (**) For the Iberian exception, the price of the gas used is determined by the MIBGAS price if it remains below the government-set limit; otherwise, the limit applies when the gas price exceeds it.

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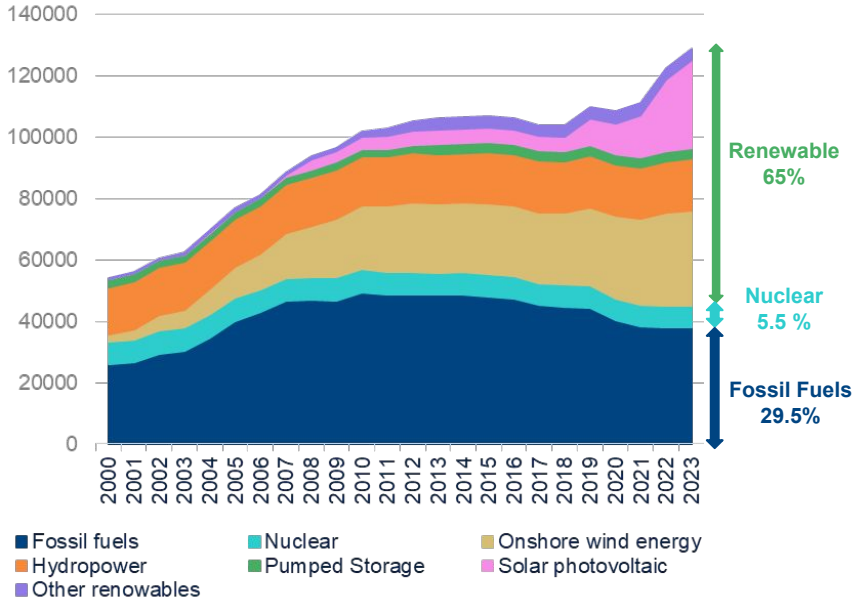
02

Spain, a European Leader in Renewable Energy Sources

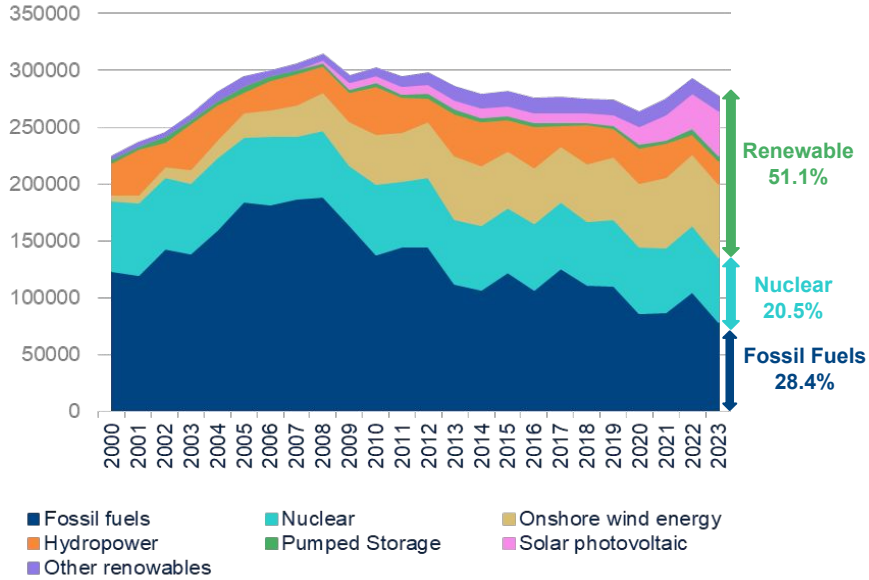
Renewable electricity capacity is growing rapidly, which is allowing to increase the use of clean technologies in power generation

SPAIN. ELECTRICITY CAPACITY BY SOURCE
(MW)



Source: BBVA Research from IRENA data.

SPAIN. ELECTRICITY MIX BY SOURCE (*)
(GWH, SEE EUROPE)

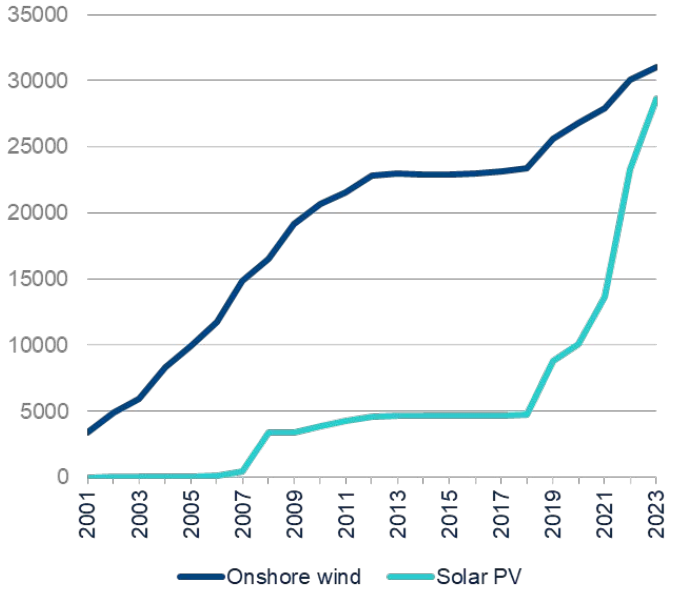


Source: BBVA Research from IRENA data. (*) For 2023 we assume that the variables growth rates are those estimated by EMBER.

Spain is a European leader in renewable energy sources

Wind energy penetration began around 2000, nearly a decade before solar, though both now have similar installed capacity

SPAIN. INSTALLED CAPACITY OF WIND AND SOLAR
(MW; 2000-2023)

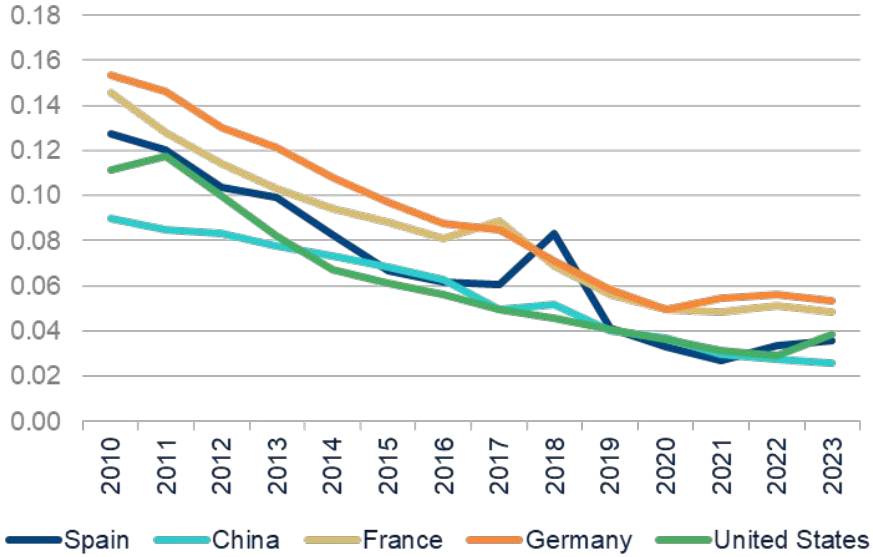


Source: BBVA Research from IRENA data.

- Investment in onshore wind energy began in Spain in 2000, increasing its installed capacity steadily by 20,500 MW until 2012. In 2013-2018, this capacity stabilised, raising again from 2019 onwards.
- The penetration of solar photovoltaic (PV) energy began in 2008, although it did not pick up again until 2018, when its installed capacity started an upward trend, coming very close to that of wind in 2023.
- Between 2018 and 2023 the installed capacity of renewables doubled in Spain, mainly due to solar, whose capacity increased fivefold. Wind power capacity increased by 33%.

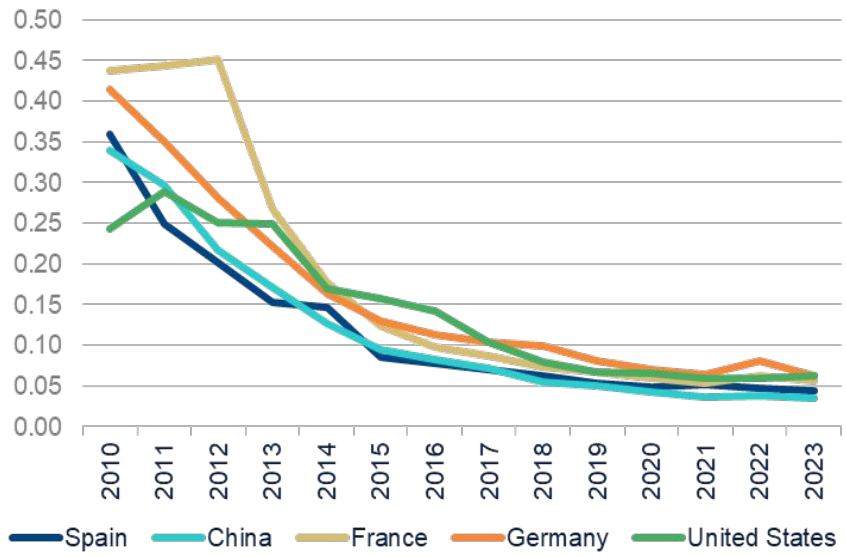
Technological advances, measures to promote green transition, and economies of scale, lead to lower production costs of renewables

LEVELIZED COST OF ELECTRICITY (LCOE) OF NEW ONSHORE WIND (2023 USD/KWH)



* LCOE is defined as the ratio between the total costs and the expected power generation during the useful life of the installation, expressed in terms of present value. It represents the per-unit cost (typically expressed in currency per kilowatt-hour, such as $/kWh or €/kWh) of building and operating a generating plant over an assumed financial life and duty cycle
Source: BBVA Research from IRENA data: Renewable Power Generation Costs in 2023

LEVELIZED COST OF ELECTRICITY (LCOE) OF NEW SOLAR PV (2023 USD/KWH)



* LCOE is defined as the ratio between the total costs and the expected power generation during the useful life of the installation, expressed in terms of present value. It represents the per-unit cost (typically expressed in currency per kilowatt-hour, such as $/kWh or €/kWh) of building and operating a generating plant over an assumed financial life and duty cycle
Source: BBVA Research from IRENA data: Renewable Power Generation Costs in 2023

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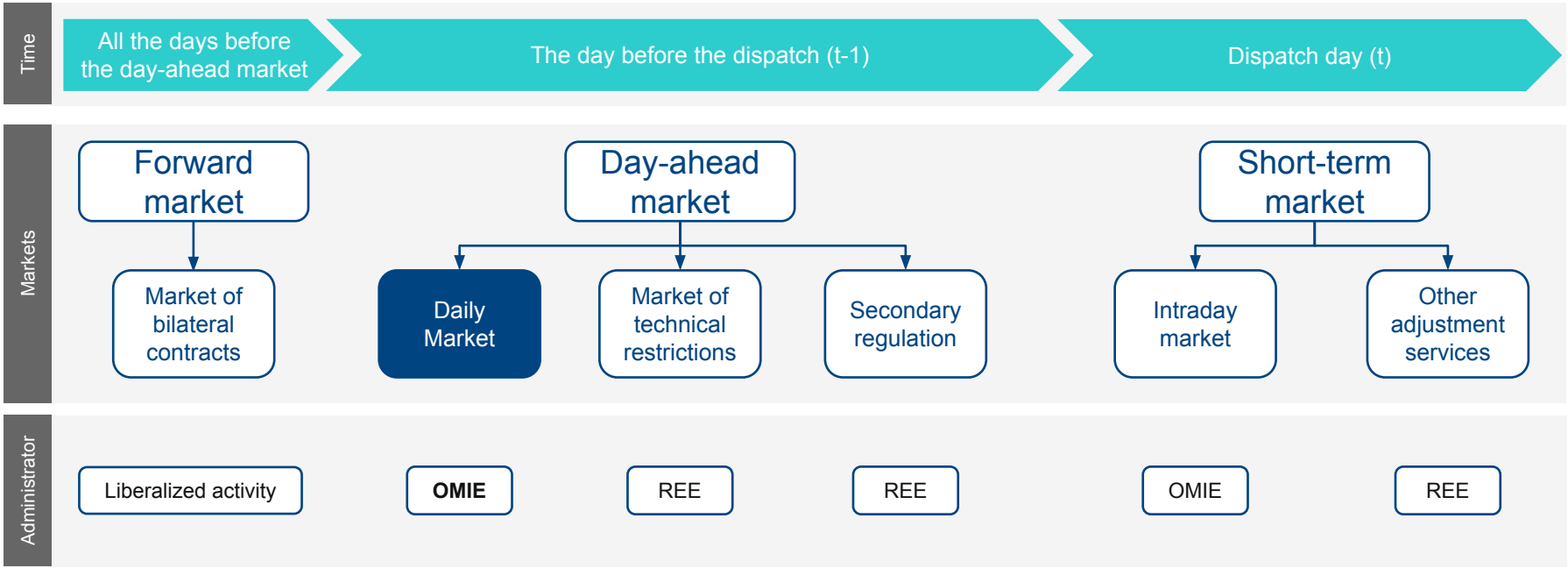
03

The Impact of Renewables on Wholesale Electricity Prices in Spain

Organization of the wholesale electricity market in Spain (more detailed)



Programa Diario Base de Casación

Programa diario base de funcionamiento

64% from Daily Market and 36% from bilateral contracts

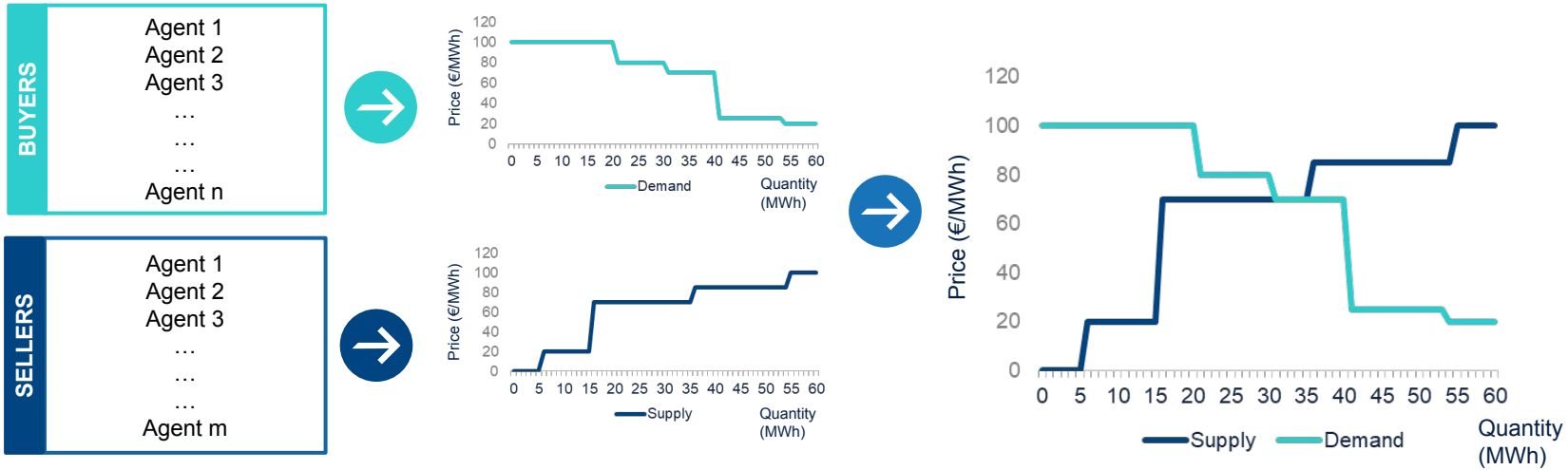
OMIE, the Daily Market and the "Programa Diario Base de Casación" (PDBC)

The day before the dispatch, the agents from Portugal and Spain make through OMIE their offers for each hour of the following day.

OMIE organizes the buyers´ offers from the highest to lowest, and the sellers´ offers from lowest to highest to estimate the Aggregate Demand and Supply curves, respectively. They are estimated for each hour.

The matching process is done by the Euphemia algorithm(*). This algorithm optimize the welfare, corresponding to the sum, over the entire time horizon, of the profits from the purchase and sale offers, along with the congestion rent. The results are published in the PDBC

DEMAND AND SUPPLY MATCHING PROCESS PER HOUR THE DAY BEFORE THE DISPATCH (t-1)

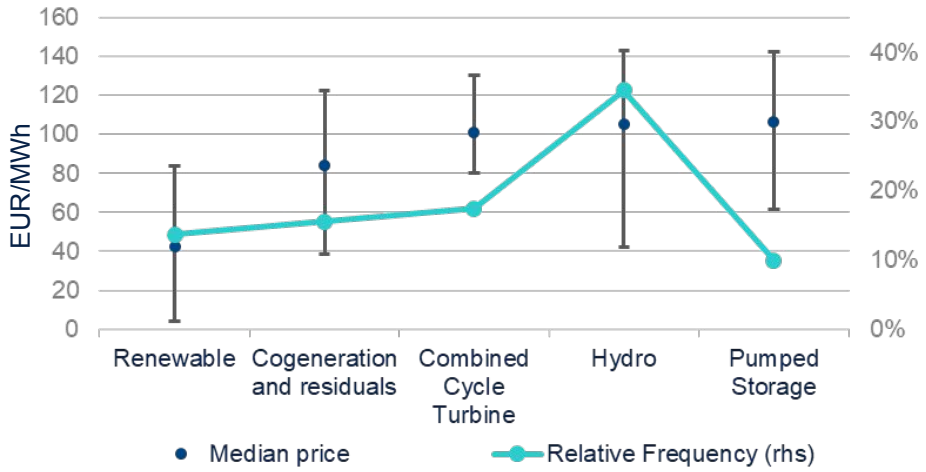


Source: BBVA Research following Energía y Sociedad. (*)The Euphemia algorithm is used by 23 European countries.

Renewables help reduce electricity prices, but set marginal prices less often than other technologies due to their low capacity factor (intermittency and lack of storage)

MARGINAL PRICES IN DAILY MARKET BY TECHNOLOGY

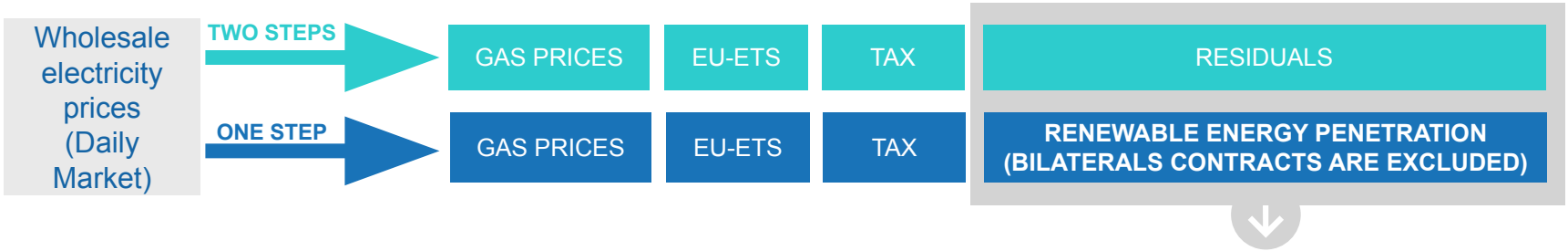
(EUR/MWh and %; 2023) (*)



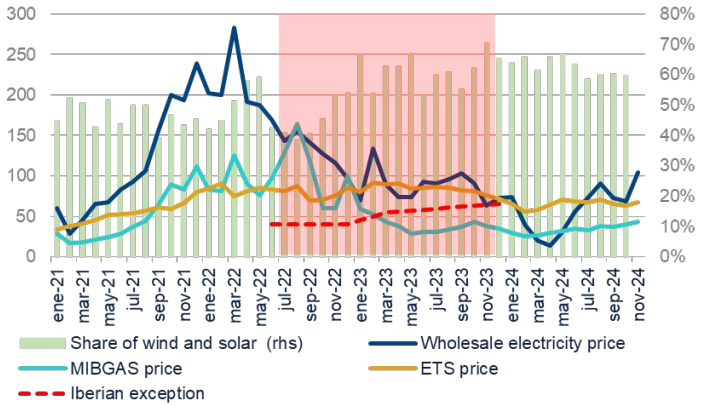
(*) Due to data availability, to distinguish between renewable and cogeneration and residuals the following criteria has been used: “When the share of renewable is above 70% and the cogeneration and residuals below 15%, a renewable technology is considered as the marginal. In other cases, cogeneration and residual are the marginal technology”.
Source: BBVA Research from OMIE data.

- In Spain, wholesale electricity prices are mostly set by Hydro (almost 34%) and Combined-cycle (17%), both technologies with high opportunity costs and feasible storage. Combined-cycle power sets the marginal price when demand cannot be met by cheaper sources.
- Electricity price is more than halved (median) when renewables (wind and solar) set the marginal price -technologies with very low costs that shift the supply curve to the right, reducing the marginal price. However, these sources depend on weather and have limited storage, so they set prices less often than other sources (14% of the time in 2023).

A dual strategy for estimating the impact of renewable energy penetration on wholesale electricity prices in Spain

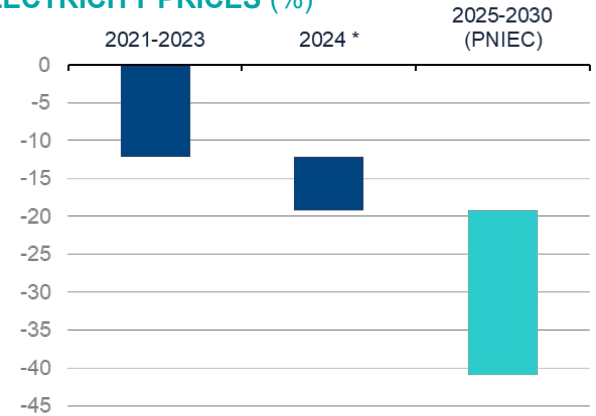


WHOLESALE ELECTRICITY AND GAS PRICES. COMBINED-CYCLE SHARE (EUR/MWh, left; %, right). 2021-2024



Source: BBVA Research from OMIE data.

IMPACT OF RENEWABLE ENERGY IN WHOLESALE ELECTRICITY PRICES (%)



Source: BBVA Research from OMIE, MIBGAS, SENDECO data and PNIEC. *The estimation is based on the available data up to June 2024.

Methodology: A two-step approach to quantify the impact of renewable energy sources on wholesale electricity prices

1. A regression model (2018-2023) where the hourly electricity price is determined by traditional factors (gas price, ETS)

$$P_{h,t,t-1} = \beta_0 + \beta_G * MIBGAS_{t,t-1} + \beta_{ETS} * ETS_{t,t-1} + \beta_{IVPEE} * IVPEE_t + \varepsilon_{h,t,t-1}$$

$P_{h,t,\,t-1}$ is the hourly one day-ahead wholesale electricity price; **$MIBGAS_{t,\,t-1}$** the one-day ahead MIBGAS price (*), **$ETS_{t,t-1}$** the one-day ahead ETS price, **$IVPEE_t$** a dummy variable equal to 1 if $IVPEE_t$= 7% and 0 if $IVPEE_t$= 0% (**) and **$\varepsilon_{h,t,\,t-1}$** the residuals (***).

2. A residual quantile regression to estimate the potential contribution of renewables to reducing electricity prices

$$\frac{\varepsilon_{h,t,t-1}}{E[P_{h,t,t-1}]} = \gamma_{0,k} + \gamma_{1,k} * Share\ wind\ and\ solar_{h,t,t-1} + u_{h,t,t-1}$$

Share wind and solar$_{h,t,\,t-1}$ is the hourly one day-ahead percentage of electricity demand covered by wind and solar energy, **$E[P_{h,t,\,t-1}]$** is the expected value of **$P_{h,t,\,t-1}$** and **$u_{h,t,\,t-1}$** the quantile model residuals.

Quantile regression (Koenker and Bassett, 1978) is an estimation method that relies on minimizing weighted absolute deviations with asymmetric weights, **making it robust to extreme data points**.

(*) The one day ahead MIBGAS price is substituted by the limit set by the government during the Iberian exception when it is above that limit (June 2022 to March 2023).
(**) Impuesto sobre el valor de producción energética (Tax over the value of the energy production). (***) The residuals represent the part of electricity prices not explained by traditional factors. This is usually due to a change in the technology that set the marginal price, but it could be also due to a change in productivity or other factors.

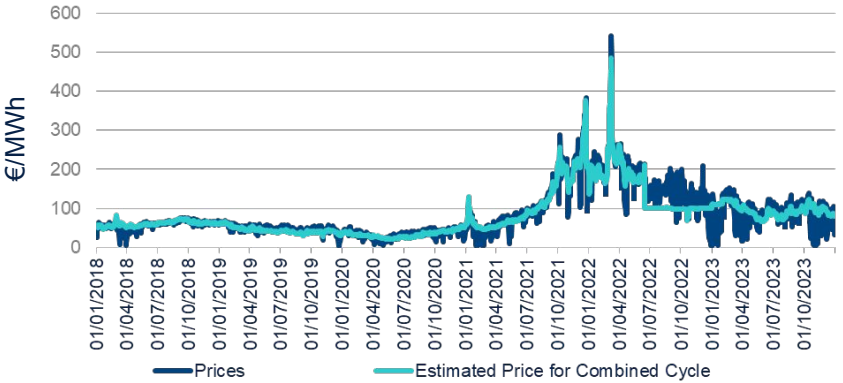
1.- A regression model to estimate hourly electricity prices based on traditional factors

ESTIMATED REGRESSION MODEL
(HOURLY DATA. 2018-2023*; OLS ESTIMATION)

	One day ahead wholesale electricity
(Intercept)	4.75***
	(0.44)
One day ahead MIBGAS	2.104***
	(0.0055)
One day ahead ETS	0.134***
	(0.006)
IVPEE	3.324***
	(0.33)
R^2	0.86

t statistic in parenthesis
* p<0.1, ** p < 0.05, *** p< 0.01

DAILY WHOLESALE ELECTRICITY PRICES AND ESTIMATED PRICES BASED ON TRADITIONAL FACTORS
EUR/MWH

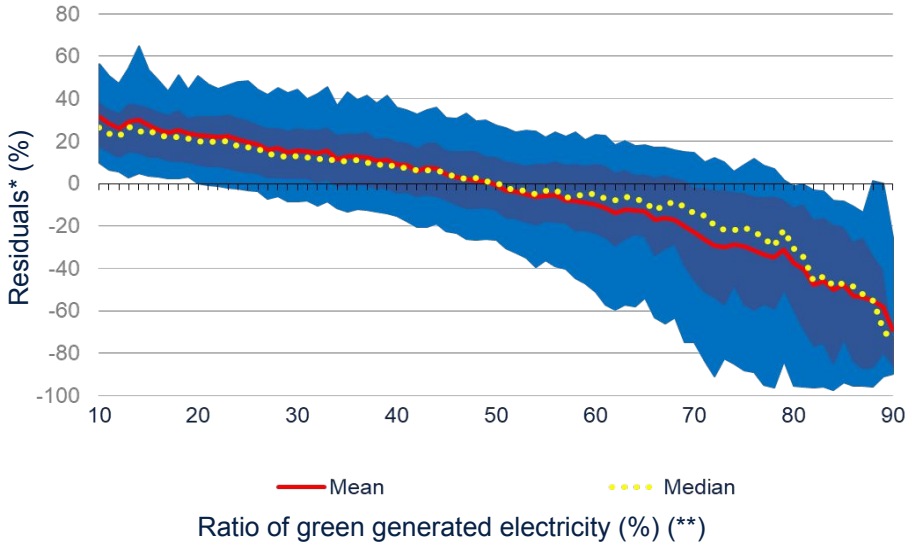


Source: BBVA Research from OMIE, MIBGAS and SENDECO data. * The period June-December 2022 was excluded due to the Iberian Exception effect together with a greater influence of coal on the marginal price.

- Natural gas prices (MIBGAS) and to a lesser extend ETS, are the two main factors determining wholesale prices.
- Taxes on energy production (IVPEE) have an upward impact on electricity prices.
- The residuals capture the part of the hourly price not explained by gas prices and emission allowances, that is, other factors affecting wholesale electricity prices (demand, renewables,...).

2.- A negative and non-linear relationship between residuals and the share of renewable energy sources

RESIDUALS AND SHARE OF RENEWABLE ENERGY IN THE ELECTRICITY MIX (HOURLY DATA; 2018-2023)



(*) $\varepsilon_{h,t,t-1}$ / E[$P_{h,t,t-1}$] (**) Green technologies refers mainly to Wind and Solar energy. Bilateral contracts have been excluded. Blue areas represent the 10, 25,75 and 90th percentile.
Source: BBVA Research from OMIE, SENDECO and MIBGAS data.

- There is empirical evidence of a negative relationship between the share of renewables (bilateral contracts excluded**) and wholesale electricity prices, as the supply of renewables displace the price set by the combined cycle technology, decoupling electricity prices from its traditional factors
- The relationship between the share of wind and solar on electricity mix and residuals of the first regression model is not linear due to the "merit order pricing system". The estimated quantile regression shows that the impact of renewables' share on residuals varies between quantiles.
- Residual heteroskedasticity at high levels of renewable penetration is also consistent with the relationship between them and electricity prices being less statistically significant in that case.

3.- The marginal effect of renewables on wholesale electricity prices increases as their share in the energy mix grows

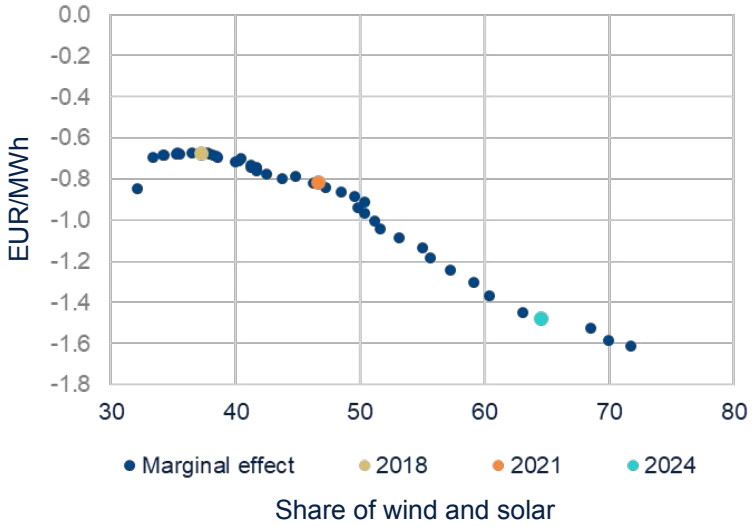
ESTIMATED REGRESSION
(HOURLY DATA; 2018-2023; QUANTILE REGRESSION)

	10th	50th	90th
(Intercept)	31.48***	36.56***	66.3***
	(0.624)	(0.286)	(0.617)
Share renewable	-1.37***	-0.74***	-0.77***
	(0.013)	(0.006)	(0.013)
Pseudo-R^2	0.29	0.15	0.1

t statistic in parenthesis

* p<0.1, ** p < 0.05, *** p< 0.01

MARGINAL EFFECT OF WIND AND SOLAR ENERGY BASED ON THEIR SHARE IN THE ELECTRICITY MIX
(EUR/MWH)



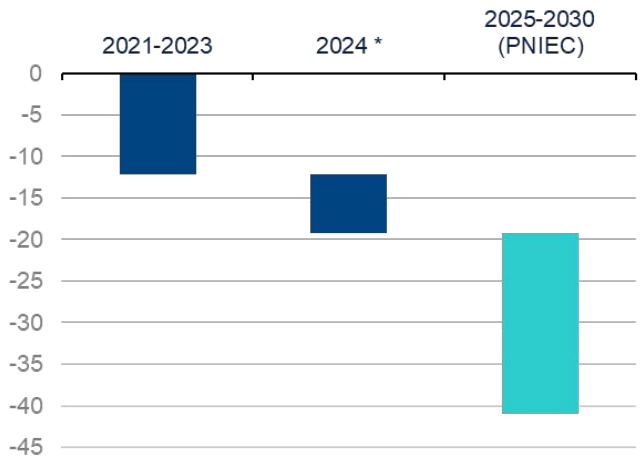
Source: BBVA Research from OMIE, MIBGAS, SENDECO data.

The marginal effect of renewables varies across residuals quantiles, being greater when the deviation from the price determined by traditional factors is more negative

Renewable energies have reduced wholesale electricity prices in Spain by 20% over the past four years

Meeting the ambitious PNIEC 2030 target could cut prices by a further 20%

IMPACT OF RENEWABLES IN WHOLESALE ELECTRICITY PRICES IN SPAIN %



Source: BBVA Research from OMIE, MIBGAS, SENDECO data and PNIEC. *The estimation of 2024 is based on the available data up to June 2024.

- From 2021 to mid-2024, the increase in the renewable energy share from 45% to 65% is estimated to have reduced wholesale electricity prices by 20% (12.5% in 2021-2023 and 7.5% in 2024) according to BBVA Research.
- Achieving the PNIEC 2030 targets -specifically 81% (**) renewable energy in electricity generation- could reduce electricity prices by a further 20%. Objectives that, while plausible, may seem optimistic over a five-year horizon given the available evidence (***).

(**) This target is equivalent to 80% excluding hydro and bilateral contracts in the Daily market. It is noteworthy that this estimate depends on maintaining the ceteris paribus assumption of the model and on the absence of significant changes in omitted variables, such as energy storage.
(***) See Más ambición climática que concreción

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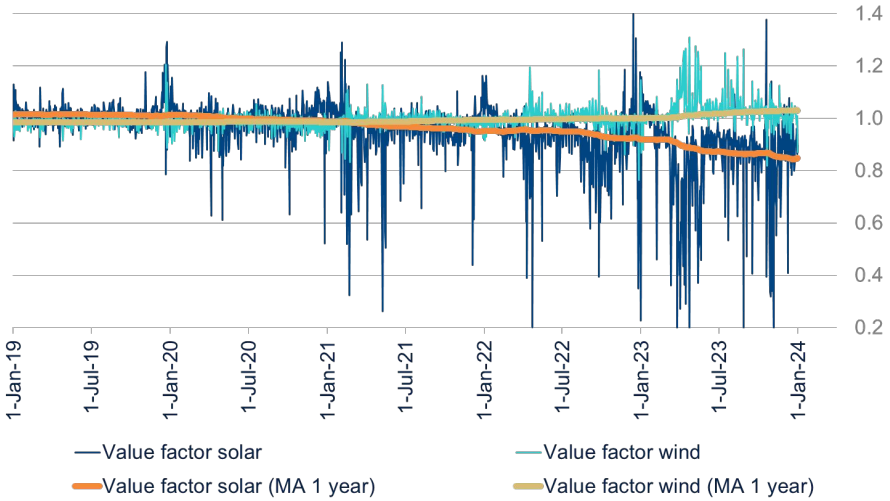
04

The “Merit-order effect” and Investment in Renewables in Spain

Greater renewable penetration lowers electricity prices through the "merit order effect"

SOLAR AND WIND DAILY VALUE FACTORS (VF)*
(2019-2023)



Source: BBVA Research from OMIE, MIBGAS, SENDECO data.
*VF: Value factor is calculated as a ratio between daily unit revenues (UR) and average electricity prices, based on hourly data of day-ahead. UR is defined as the generation weighted electricity prices.

$$UR_t^{\{s,w\}} = \frac{\sum_{h=1}^{24} p_h \, q_h^{\{s,w\}}}{\sum_{h=1}^{24} q_h^{\{s,w\}}} \qquad VF_t^{\{s,w\}} = \frac{UR_t^{\{s,w\}}}{\bar{p}_t}$$

- "Merit-order effect" refers to an economic phenomenon in electricity markets where for any given demand, low marginal cost electricity technologies (such as solar and wind) entering the market, shift the supply curve to the right and the marginal price decline.
- This price drop could reduce the income of renewable energy generators, and even discourage investment in these technologies, a phenomenon known as "cannibalization".
- Considering López et al. (2020), we analyzed the "cannibalization" effect of wind and solar in the Daily market in Spain.
- While solar and wind value factors were very similar until mid-2021, from then on the solar value began a downward trend not observed in that of the wind.

Lower energy prices have reduced solar and wind unit revenues, especially for solar

ESTIMATED QUANTILE REGRESSION

DAILY DATA. 2018-2023 (*)

	Wind UR			Solar UR		
	10th	50th	90th	10th	50th	90th
(Intercept)	12.86***	7.87***	6.31***	21.44***	11.5***	9.1
	(3.51)	(1.03)	(1.12)	(3.17)	(1.24)	(1.25)
Solar supply	0.15***	-0.003	-0.016	-0.063	-0.082***	-0.08***
	(0.05)	(0.015)	(0.017)	(0.05)	(0.02)	(0.02)
Wind supply	-0.23***	-0.097***	-0.055***	-0.23***	-0.09***	-0.045***
	(0.016)	(0.005)	(0.005)	(0.015)	(0.006)	(0.006)
Non-renewable supply	0.05***	0.05***	0.055***	0.07***	0.07***	0.06***
	(0.015)	(0.004)	(0.05)	(0.013)	(0.005)	(0.005)
One day ahead MIBGAS	2.03***	2***	2.11***	2.01***	2.01***	2.1***
	(0.044)	(0.013)	(0.014)	(0.04)	(0.015)	(0.016)
One day ahead ETS	-0.06	0.32***	0.365***	-0.21***	0.18***	0.3***
	(0.07)	(0.02)	(0.024)	(0.066)	(0.026)	(0.026)
Pseudo-R^2	0.61	0.8	0.91	0.52	0.75	0.89

t statistic in parenthesis

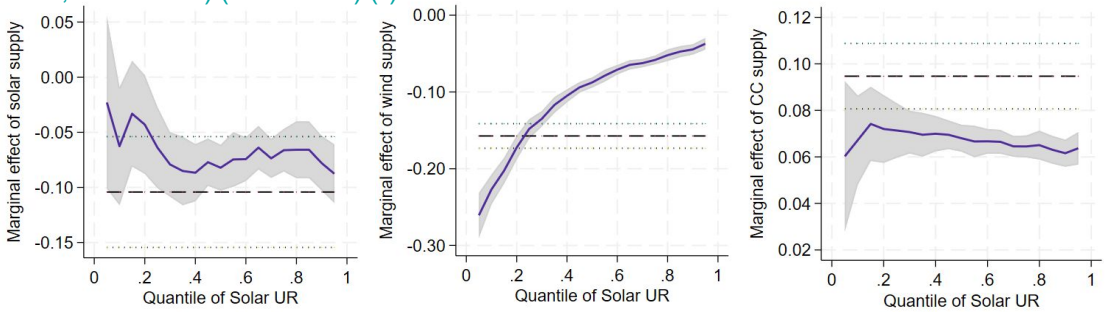
* p<0.1, ** p < 0.05, *** p< 0.01

- For solar, its penetration negatively affects sector revenues (auto effect), aligning with OLS estimates. Wind supply also reduces solar unit revenues (cross effect), especially when revenues are low.
- In the case of wind energy, its effect on generator revenues is significant and non-linear, with a stronger impact when revenues are lower. However, the cross effect of solar on wind is significant only in revenue quantiles below 30th. This may be due to higher solar prices in these quantiles compared to wind.
- Natural gas prices, the EU-ETS, and combined cycle supply have a positive impact on solar and wind revenues.

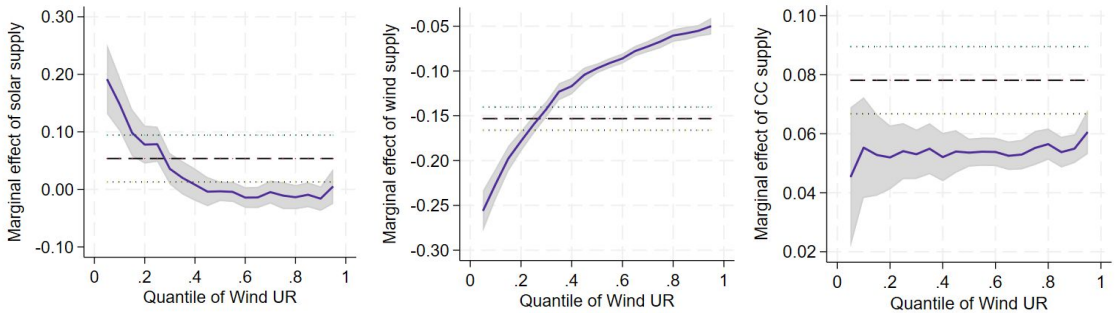
Source: BBVA Research from OMIE, MIBGAS and SENDECO data based on "The cannibalization effect of wind and solar in the California wholesale electricity market". Summary of variables

Lower energy prices have reduced solar and wind unit revenues, especially for solar

"MERIT-ORDER EFFECT" IN SOLAR UNIT REVENUES (DAILY DATA; 2018-2023) (EUR/GWh) (*)



"MERIT-ORDER EFFECT" IN WIND UNIT REVENUES (DAILY DATA; 2018-2023) (EUR/GWh) (*)



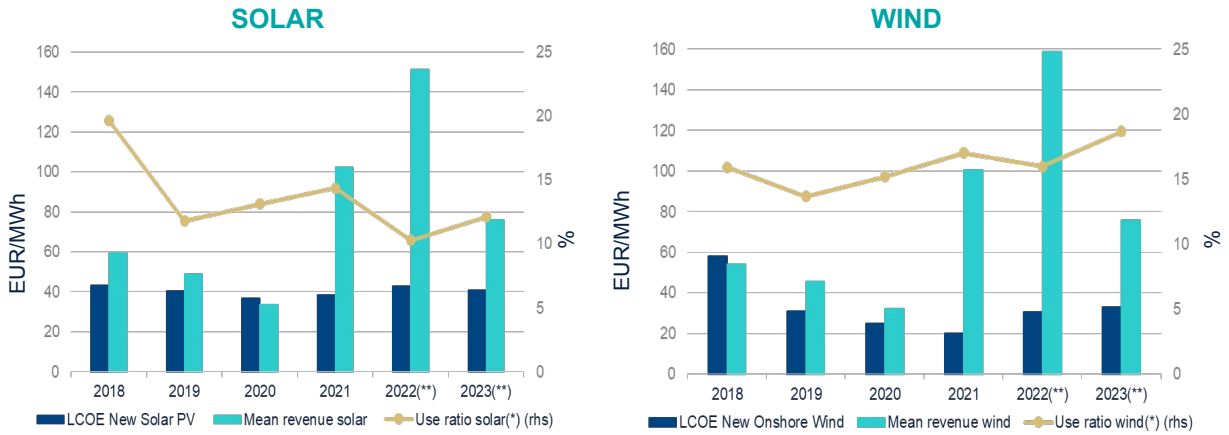
(*) The cannibalization effect of wind and solar , Summary of the main variables. (**) The dashed line represents the OLS estimation and the 95% confidence interval, while the blue line represents the Quantile estimation of the parameter for each quantile and the area is the 95% confidence interval of this estimation

Source: BBVA Research from OMIE, MIBGAS and SENDECO data.

There is no clear evidence of a discouragement of investment in renewables

SOLAR AND WIND. REVENUES, LCOE AND USE RATIO (*)

(EUR/MWH, LEFT; % RIGHT)

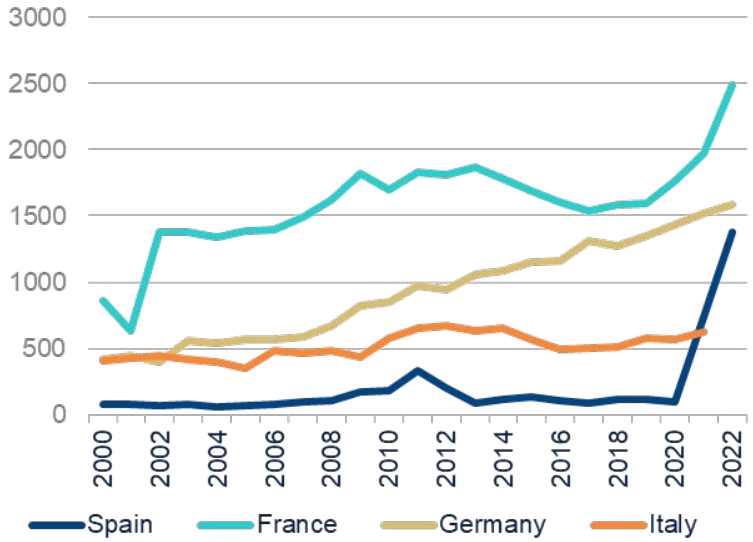


- Solar and wind energy revenues closely followed new installation costs from 2018 to 2020, but since 2021, revenues have grown faster than costs.
- This surge in revenues does not appear to be related to a lower use ratio of these technologies.
- Renewable energy revenues remain highly dependent on natural gas prices, which have enabled them to generate sufficient income to offset potential losses when they set the marginal price.

Source: BBVA Research from IRENA, OMIE and FRED data.
(*) The use ratio is defined as the demand satisfied (by wind or solar) in the daily market over its installed capacity.
In 2022 and 2023 due to the Iberian exception the revenues of renewables sources were smaller than the ones given by this results.

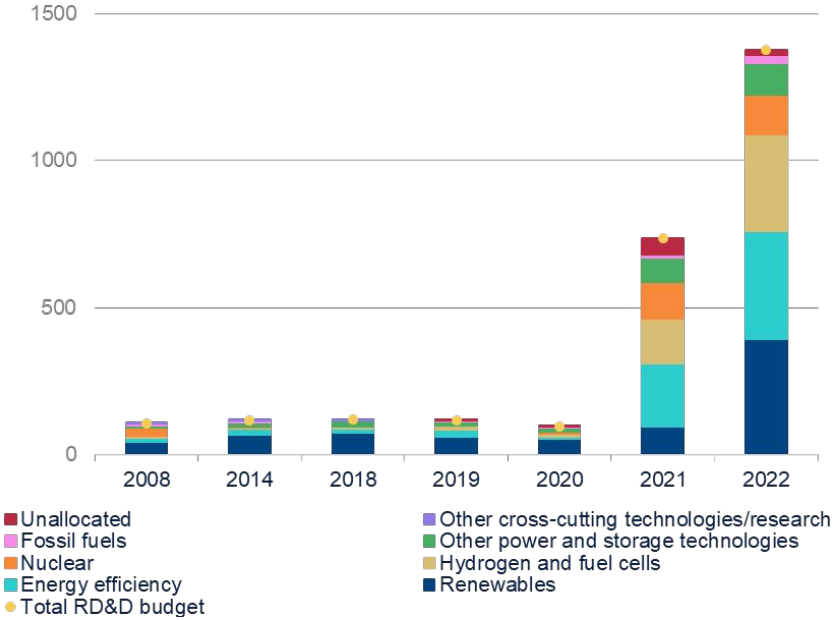
Public investment in energy R&D is increasing since 2020, mainly driven by the NGEU funds

PUBLIC ENERGY RD&D INVESTMENT
(CONSTANT MILL € 2023)



Source: BBVA Research from IEA data.

SPAIN. PUBLIC ENERGY RD&D INVESTMENT BY TECHNOLOGY (CONSTANT MILL € 2023)



Source: BBVA Research from IEA data.

Further regulatory advancements and investment will be needed

A more flexible regulation at national and European level:

- Greater legal certainty.
- Streamline the processing and issuance of permits by the Public Administrations.
- Simplify the procedure for obtaining access and connection permits to the grid.
- Rapid repowering of renewable energy facilities (e.g. wind).
- Proactive de-risking policies, bolster clean tech manufacturing and mobilize public and private investment.

Bolster clean-tech manufacturing and mobilize public and private investment:

- Market integration, cross-border electricity trading, deployment of renewables.
- Robust, continent-wide infrastructure networks for electricity, hydrogen, CCS.
- Establish a Savings and Investments Union and streamline funding access for clean technologies.
- Reduce time to market for clean technologies, simplify access to funds, and replicate successful execution models.

Key messages

Energy Consumption in Spain

- Spain's energy consumption is dominated by the transport, industry, and residential sectors (around 80%). Transport relies mainly on oil products while other sectors primarily use electricity and natural gas. The reliance on imported gas is significant and concentrated in a few countries.

Spain, a European Leader in Renewables

- Spain is advancing toward greater energy sovereignty through renewables. The rapid growth in renewable installed-capacity has boosted the use of them, accounting for 65% of the electricity mix in mid-2024 (without hydro and bilateral contracts).

Impact of Renewables on Wholesale Electricity Prices

- From 2021 to mid-2024, the increase in the renewable energy share from 45% to 65% is estimated to have reduced wholesale electricity prices by 20% (12.5% in 2021-2023 and 7.5% in 2024) according to BBVA Research.
- Looking ahead, meeting the PNIEC 2030 target could reduce prices by a further 20%. While plausible, this objective may seem overly optimistic over five years.

"Merit order effect" and Investment in Renewables

- Greater renewable penetration lowers electricity prices through the "merit order effect" (low marginal cost technologies, such as solar and wind, shift the market supply curve to the right and the marginal price declines), impacting their profitability. However, no evidence shows it has deterred renewable investment ("cannibalization").
- Sustaining the growth in renewables will require regulatory advancements and investment to position Spain as a leader in the energy transition, ensuring a more competitive, sustainable and resilient future.

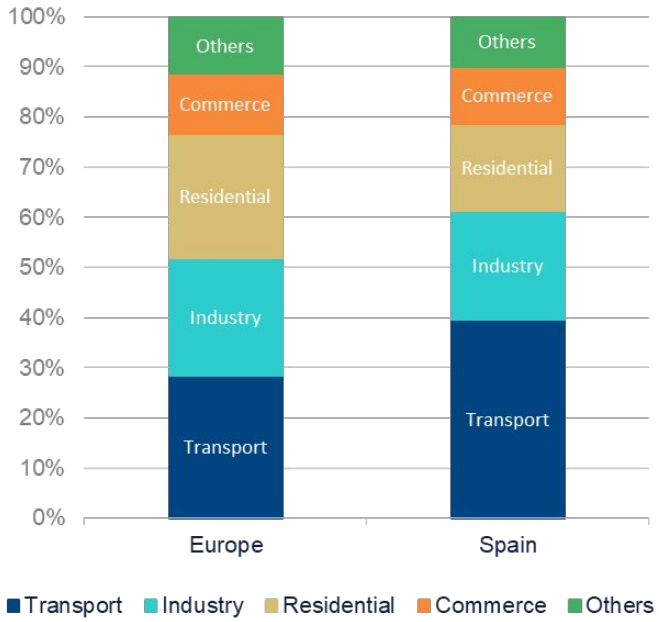
BBVA Research

ANEXO

Transport, industry and residential accounting for around 80% of total energy consumption in Europe and Spain

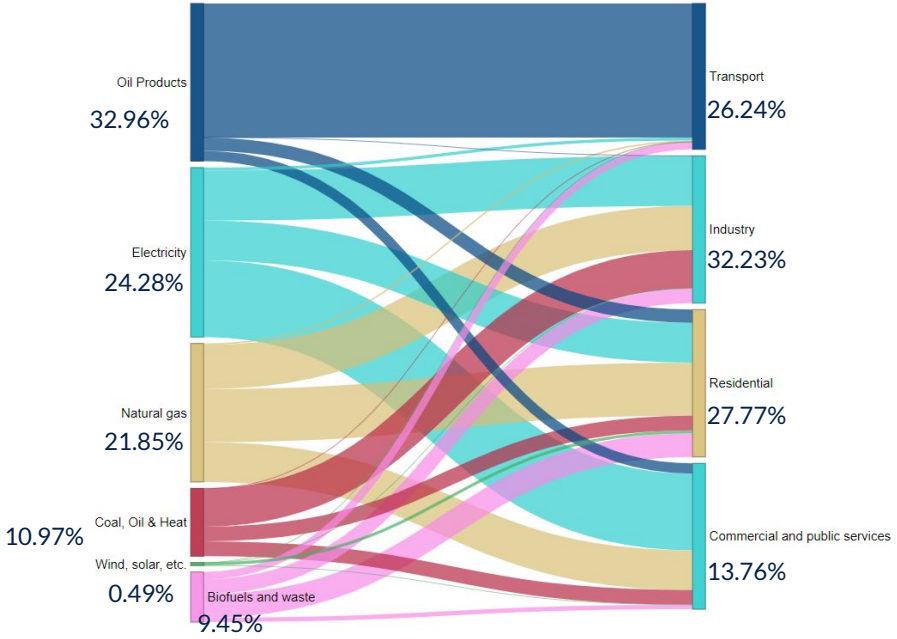
TOTAL ENERGY CONSUMPTION (TEC) BY SECTOR

2022.·% OF TEC (*)



Source: BBVA Research from IEA data. (*) Commerce includes commercial and public services.

EU. TOTAL ENERGY CONSUMPTION (TEC) BY SECTOR AND SOURCE. 2022.· % OF TEC BY SECTOR (*)

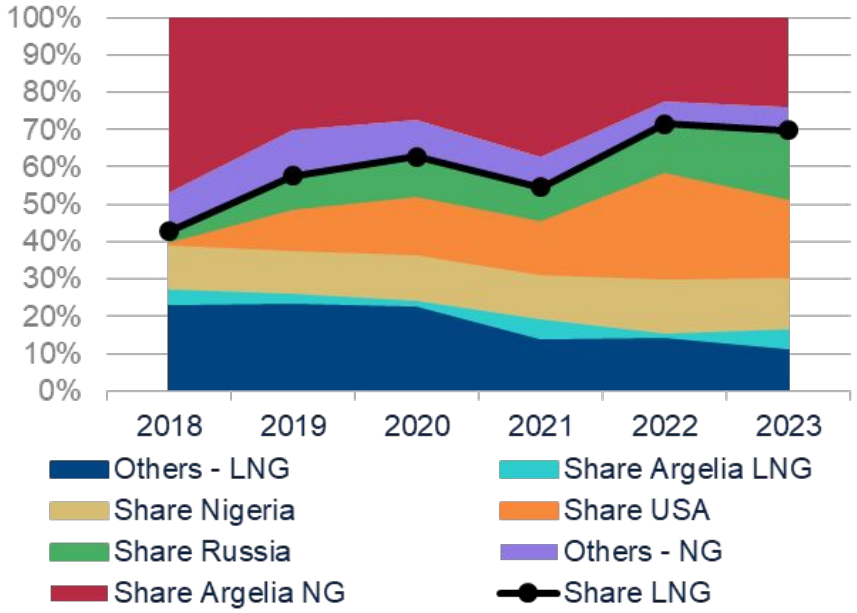


Source: BBVA Research from IEA data.

The increase in LNG imports has reduced the dependence on Algerian gas

NATURAL GAS AND LNG IMPORTS STRUCTURE OF SPAIN

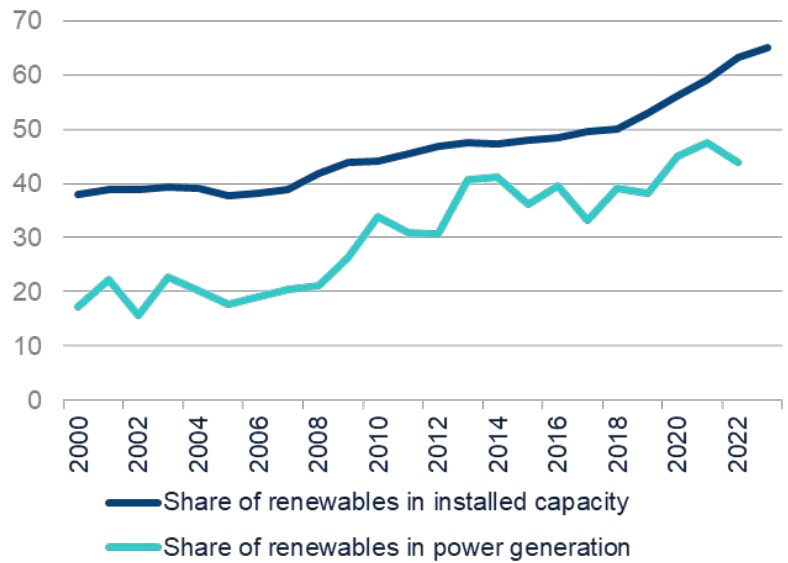
% OF TOTAL GAS IMPORTS



Source: BBVA Research with CORES data.

Renewable energy installed capacity is growing faster than its share in electricity mix

SPAIN. SHARE OF RENEWABLES IN TOTAL INSTALLED CAPACITY AND TOTAL POWER GENERATION % OF TOTAL INSTALLED CAPACITY AND TOTAL POWER GENERATION



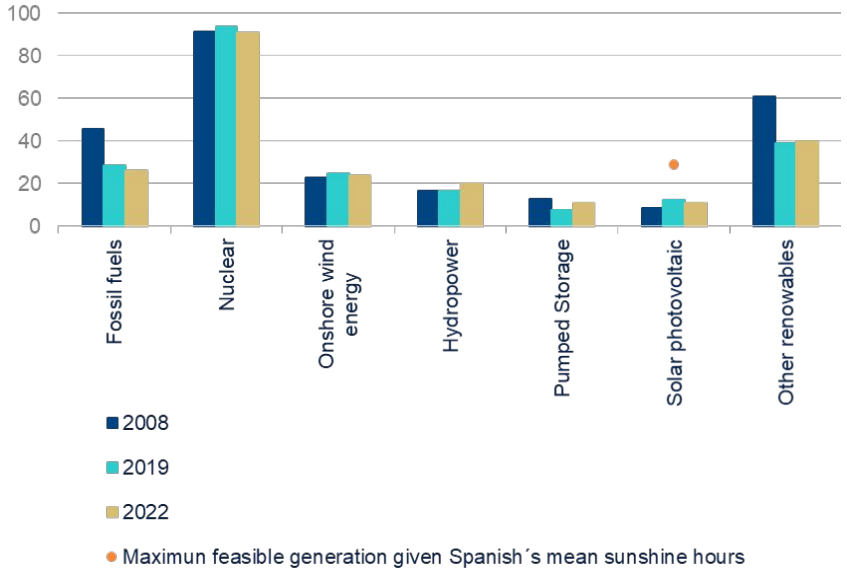
- The installed Capacity refers to the maximum theoretical power output (measured in MW) that a power plant or energy system can produce under optimal conditions. It represents the total available infrastructure and equipment for energy generation but does not reflect actual production.
- The electricity generated by a power source is the total amount of electricity produced over a specific period, typically measured in kWh or MWh. It depends on factors like resource availability (e.g., sun, wind, water), equipment efficiency, and operational conditions.

Source: BBVA Research from IRENA data.

A better use of installed capacity of renewables in power generation

HOURS PER YEAR OPERATING IN POWER GENERATION BY SOURCE

% OF TOTAL HOURS OF THE YEAR (8769 HOURS) (*)

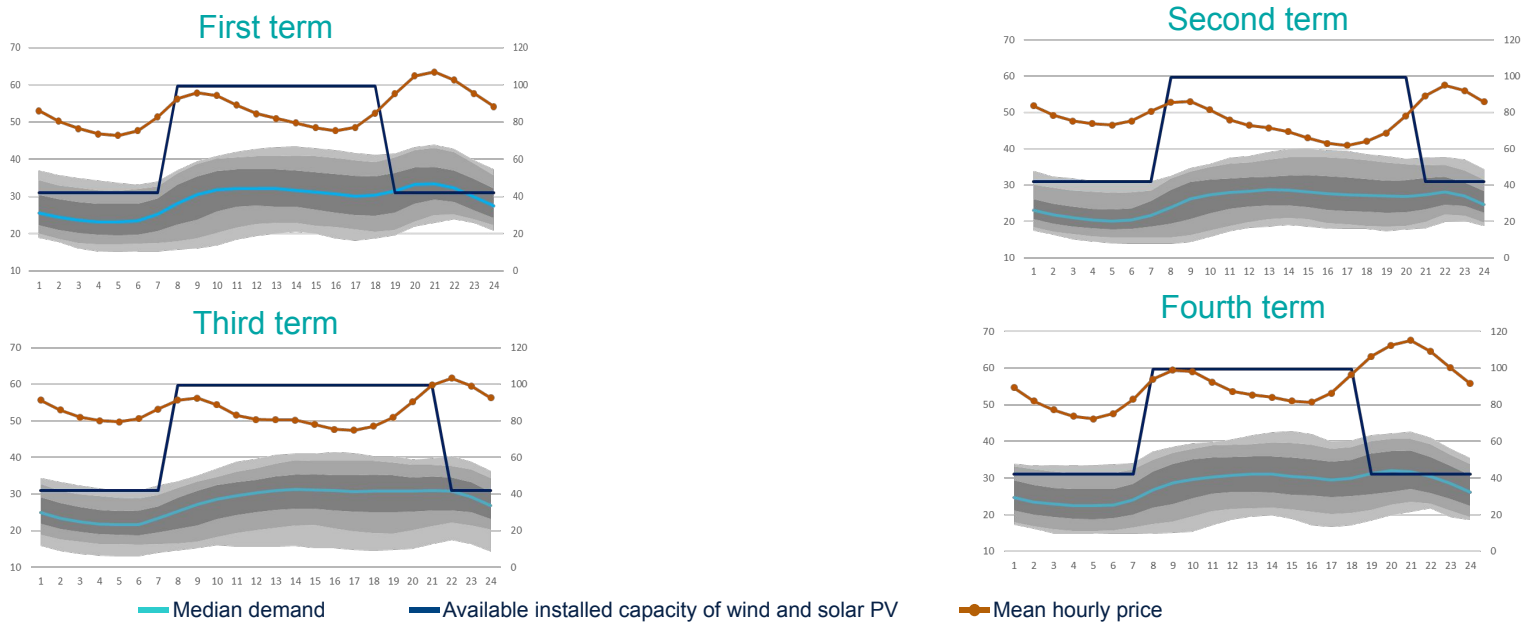


Source: BBVA Research from REData (*) 100% represents the use of the total installed capacity of a source uninterruptedly throughout the 8760 hours of the year (365*24=8760).

- Fossil fuels have significantly reduced the number of hours of energy generation per year, from 46% of the total in 2008 to 26% in 2022.
- Among renewables, onshore wind is operational for around 25% of the total hours of the year and solar PV power for 11%, both depending on weather conditions (wind and sun). By contrast, nuclear is available for 90% of the total hours.
- However, solar power is not using all the installed capacity. It operates only 40% of the total hours of sunshine per year (1000 hours compared to 2500 sunshine hours per year on average).

Making better use of installed capacity of renewables in power generation

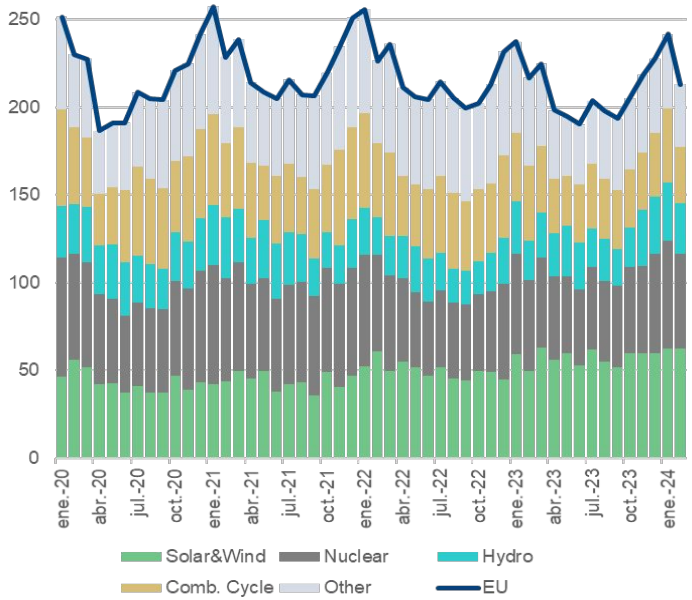
DAILY DEMAND VARIATION, WIND AND SOLAR PV AVAILABLE INSTALLED CAPACITY AND ITS EFFECT ON PRICES



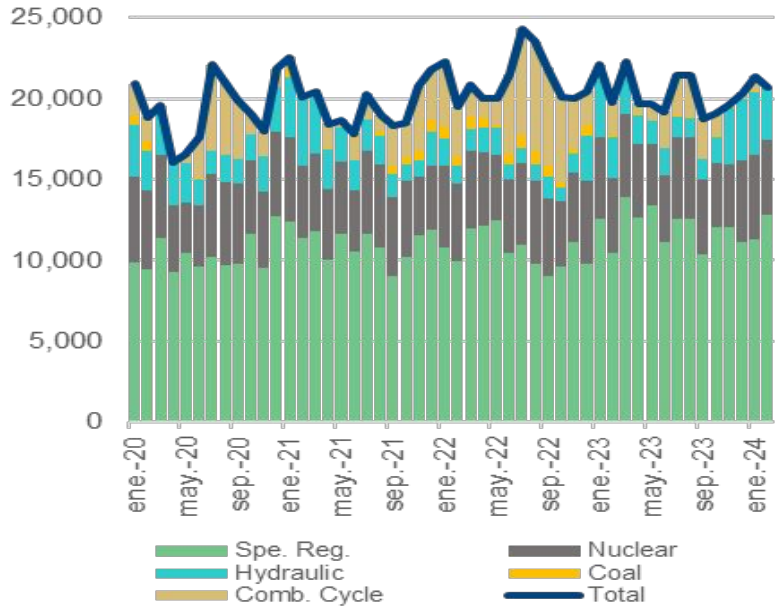
Source: BBVA Research from OMIE and IRENA data.(*)The available installed capacity is estimated as the maximum supply of energy that could be produced given the mean sunshine hours per term, and the installed capacity of wind and solar PV at the end of 2023. This estimation is independent to other climate or technical restriction that could affect the real electricity production each day.

The share of wind and solar in the Spain's electricity mix almost double that of the EU average

EU. MONTHLY ELECTRICITY MIX
TWH PRODUCED BY TECHNOLOGY. 2020-2024



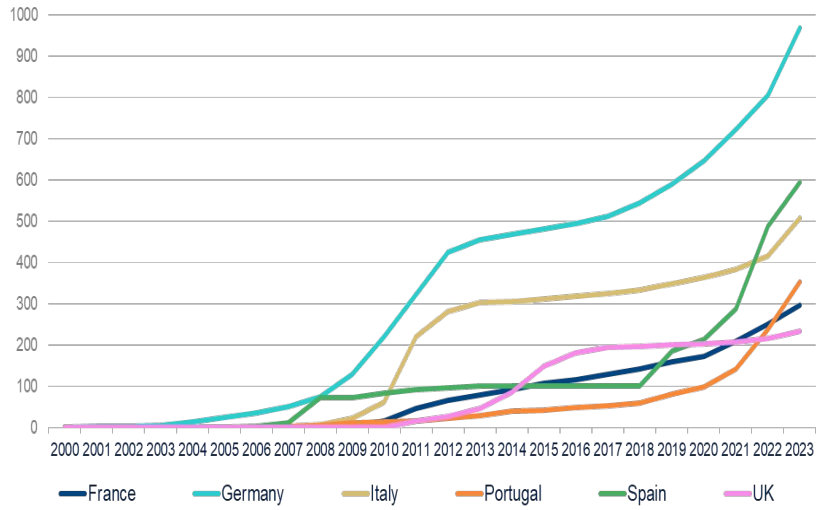
SPAIN. MONTHLY ELECTRICITY MIX
GWH PRODUCED BY TECHNOLOGY. 2020-2024 (*)



Source: BBVA Research from EMBER data. EU demand is the average demand of all EU countries (not a weighted average).(*) The renewable energy technologies under Spain's special regime (Spe. Reg.) include photovoltaic solar, thermoelectric, wind, and geothermal energy.

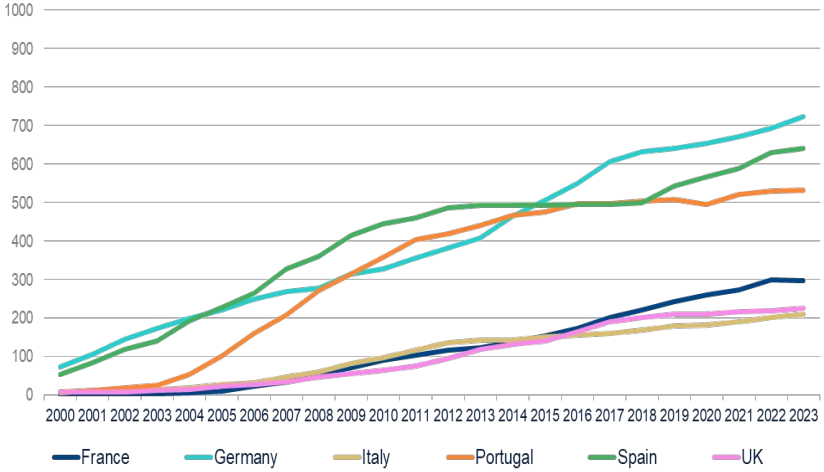
Solar and wind energy in European countries

SOLAR PV INSTALLED CAPACITY PER CAPITA
(MW/ MILL HAB)



Source: BBVA Research from IRENA data.

WIND INSTALLED CAPACITY PER CAPITA
(MW/ MILL HAB)



Source: BBVA Research from IRENA data.

The daily market is the main component of the wholesale electricity price, but the share of adjustment services is increasing with renewables

Daily Market: A market where electricity purchase and sale transactions are conducted for the entire following day, managed by the Market Operator.

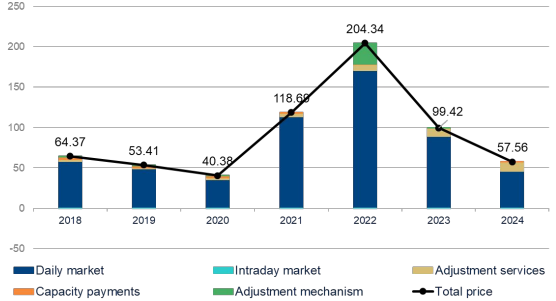
Intraday Market: A market that allows participants to adjust their energy purchase and sale positions after the Daily Market. It enables real-time corrections to balance supply and demand, addressing unforeseen changes such as weather fluctuations, renewable energy variability, or shifts in consumption.

Adjustment Services:

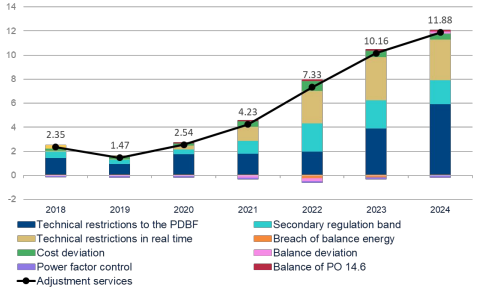
- Real-Time Technical Constraints
- PDBF Technical Constraints: A mechanism integrated into the electricity production market, managed by the system operator. It involves resolving technical constraints identified in the Daily Base Operating Schedule (PDBF) by modifying the schedules of Programming Units and subsequently rebalancing generation and demand.
- Secondary Regulation Band; Balancing Energy Non-Compliance; Imbalance Costs; Imbalance Settlements; Power Factor Control; PO 14.6 Balance

Capacity Payments: financial mechanisms designed to ensure the reliability and adequacy of the electricity system. They compensate electricity generators for maintaining available capacity to meet future demand, even if that capacity is not actively used.

COMPOSITION OF THE WHOLESALE ELECTRICITY PRICE (MWh/€)



COMPOSITION OF ADJUSTMENT SERVICES OF WHOLESALE ELECTRICITY PRICE (MWh/€)

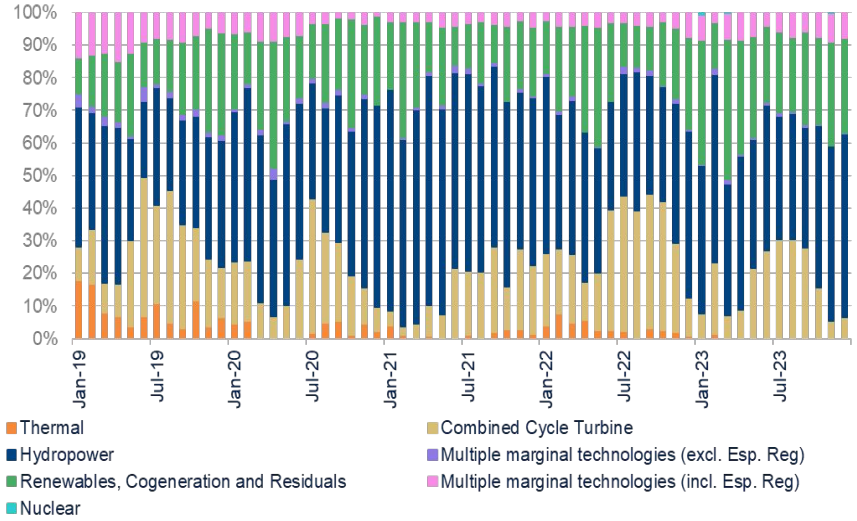


Source:BBVA Research from REData

Hydro is the technology that most often sets the marginal electricity price, though the influence of solar and wind is steadily growing

DAILY MARKET. HOURS PER MONTH SETTING THE MARGINAL PRICE BY TECHNOLOGY

2019 - 2023. (%)



- In Spain, the marginal electricity price is mostly set by Hydro and Pumped Storage technology. These technologies have high opportunity costs, so they set a price close to the estimated marginal cost for fossil fuel technologies.
- It is also remarkable the increase in hours in which the price is set by renewable energy sources in the last two years.

Source: BBVA Research from OMIE data.

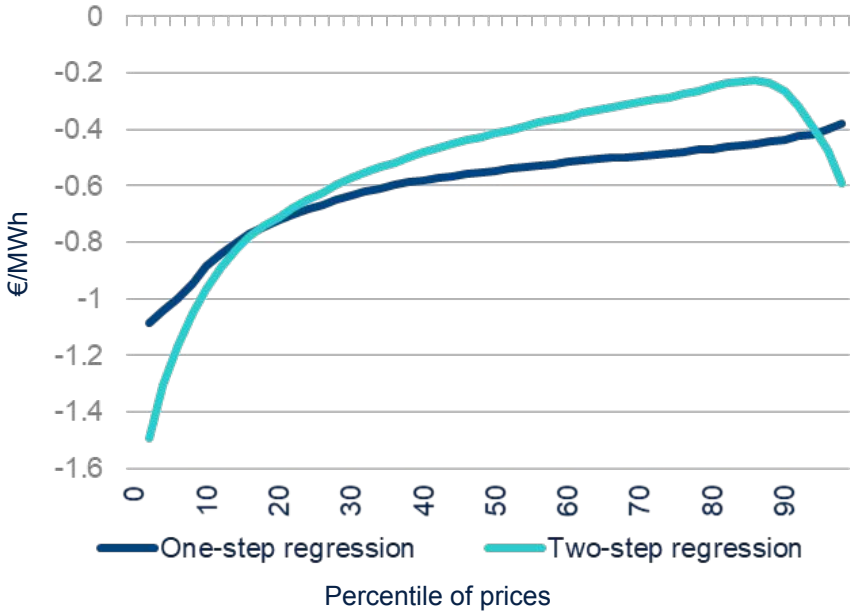
Robustness check: One step approach vs Two steps approach

	One-step			Two-step		
	10th	50th	90th	10th	50th	90th
(Intercept)	30.45***	22.84***	21.42***	21.54***	18.4***	30.3***
	(1.03)	(0.306)	(0.383)	(0.51)	(0.166)	(0.68)
One day ahead MIBGAS	1.88***	1.98***	2.21***			
	(0.0116)	(0.0035)	(0.0045)			
One day ahead ETS	0.148***	0.446***	0.54***			
	(0.0141)	(0.004)	(0.005)			
IVPEE	1.17**	1.34***	0.5**			
	(0.687)	(0.205)	(0.263)			
Share renewable	-0.886***	-0.5464***	-0.436***	-0.967***	-0.413***	-0.267***
	(0.014)	(0.004)	(0.0055)	(0.011)	(0.004)	(0.0146)
Pseudo-R^2	0.44	0.71	0.86	0.3	0.13	0.02

t statistic in parenthesis

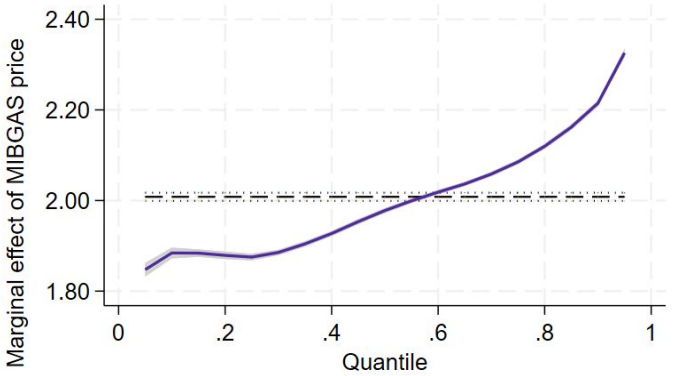
* p<0.1, ** p < 0.05, *** p< 0.01

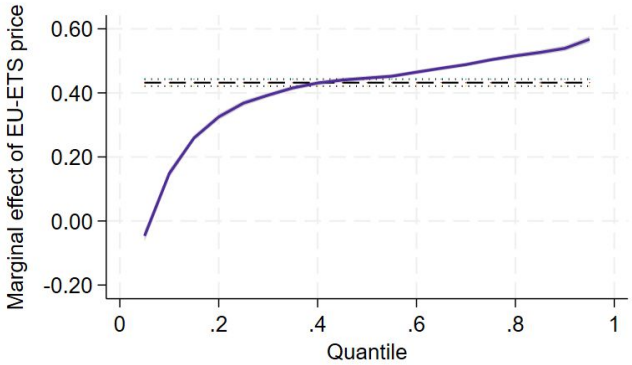
MARGINAL EFFECT OF RENEWABLES IN WHOLESALE ELECTRICITY PRICES

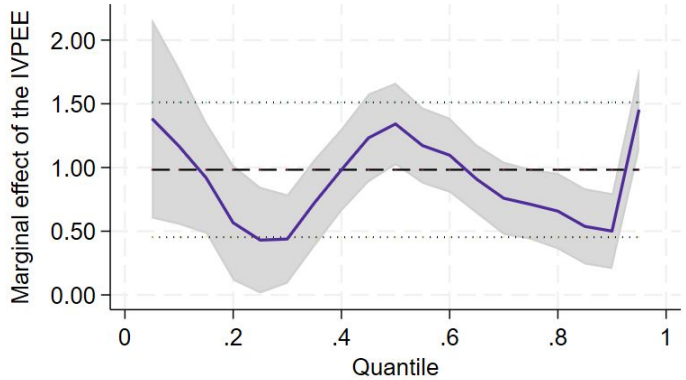


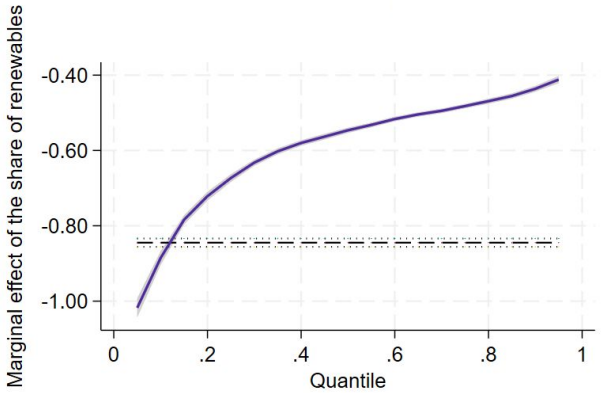
Source: BBVA from OMIE, MIBGAS and SENDECO data

One-step. The β´s of the quantile regression









Source: BBVA Research from OMIE, SENDECO and MIBGAS data

Impuesto sobre el valor de la producción de energía eléctrica

Taxable event

The taxable event consists of the production and incorporation of electricity, measured at the power plant busbars, into the electrical energy system (including the mainland electricity system as well as island and extra-mainland territories). Electricity production measured at the busbars corresponds to the electricity measured at the alternator terminals, minus auxiliary generation consumption and losses up to the grid connection point.

Taxpayers include individuals, legal entities, and the entities referred to in Article 35.4 of the General Tax Law that engage in activities constituting the taxable event. This applies to both conventional electricity generation facilities and those producing electricity from renewable energy sources, cogeneration, or waste.

Type of tax

7% throughout 2022, but the tax was suspended in 2023 and reintroduced progressively in 2024.

- 7% in 2018 (January–June) and from 2019 to 2021 (January–June).
- 0% in 2018 (July–December), 2021 (July–December), 2022, and 2023.

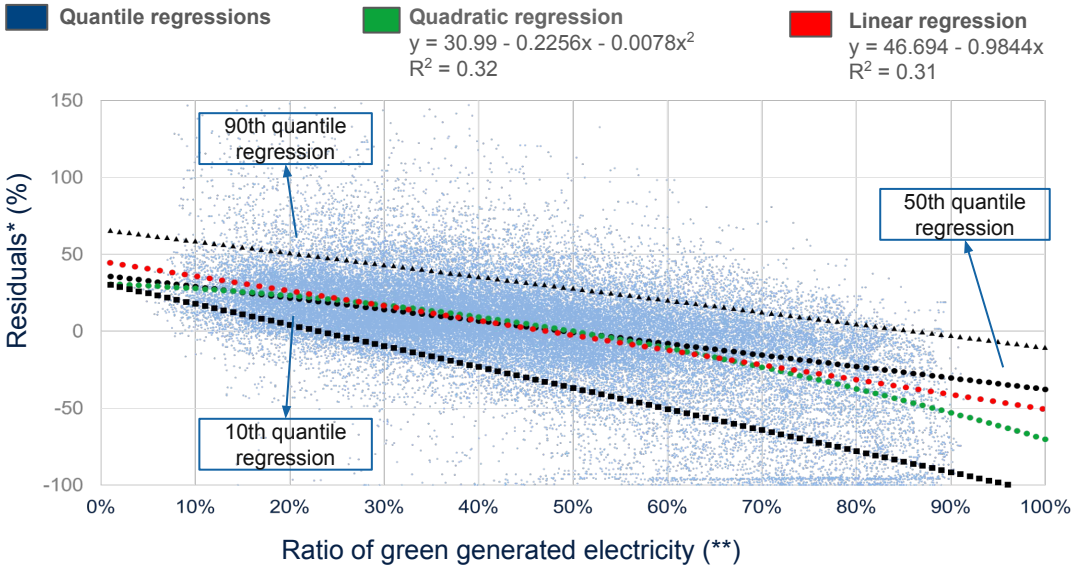
Tax in 2024:

The government approved the reactivation of the tax at **7% for 2024**, but applied a **50% reduction in the first quarter** and a **25% reduction in the second quarter.**

A negative and non-linear relationship between residuals and share of renewables

RESIDUALS AND SHARE OF RENEWABLES IN ELECTRICITY MIX

HOURLY DATA. 2018-2023



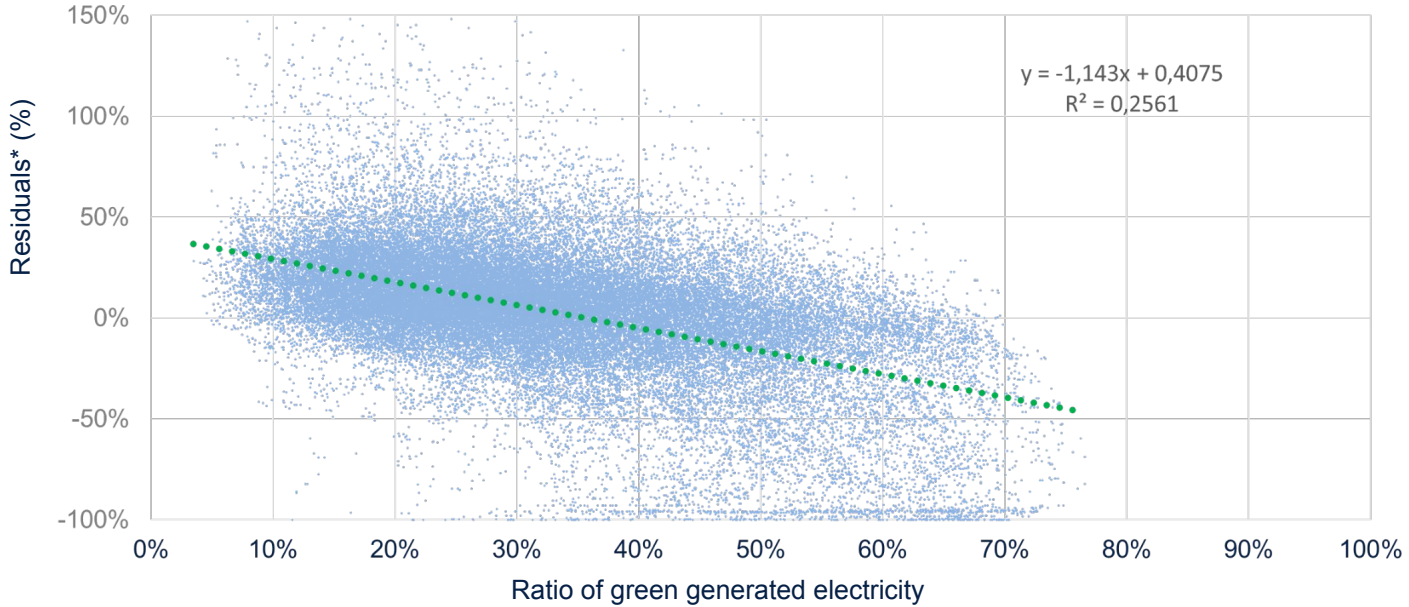
- There is empirical evidence of a negative relationship between the share of renewables (bilateral contracts excluded**) and wholesale electricity prices, as the supply of renewables displace the price set by the combined cycle technology.
- The relationship between the share of wind and solar on electricity mix and residuals of the first regression model is not linear due to the "merit order pricing system". The estimated quantile regression shows that the impact of renewables' share on the residuals varies between quantiles.

(*) $\varepsilon_{h,t,t-1}$ / E[$P_{h,t,t-1}$] (**) Green technologies refer to Wind and Solar energy. Bilateral contracts have been excluded, which is a difference from the analysis carried out by the BdE (see here). Moreover, we used data from Programa Diario Base de Casación and data of BdE are taken from ENTSO-E.
Source: BBVA Research from OMIE, SENDECO and MIBGAS data.

The penetration of renewables is helping to reduce electricity prices

With bilateral contracts

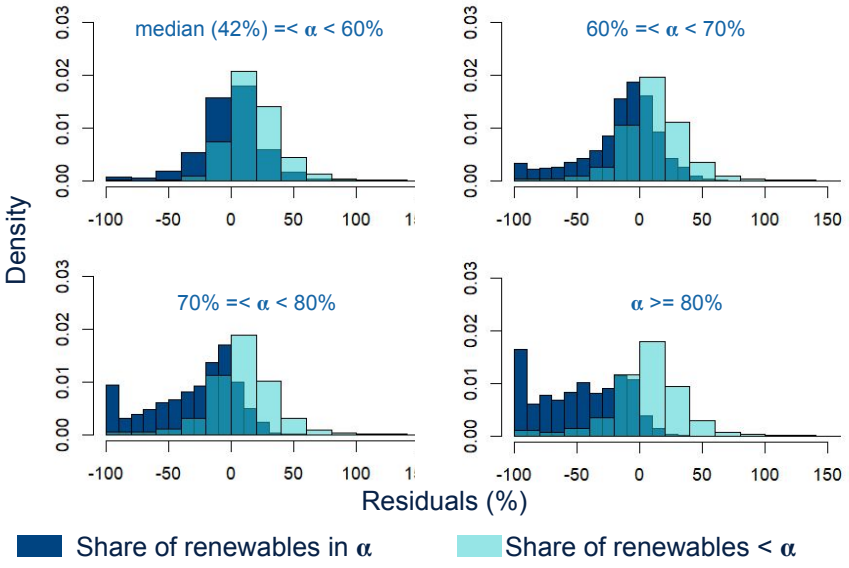
SCATTERPLOT OF THE RESIDUALS VS THE SHARE OF RENEWABLES IN ELECTRICITY MIX (2018-2023)



(*)Residuals = $\varepsilon_{h,t,t-1}$ / E[$P_{h,t,t-1}$]
Source: BBVA Research from OMIE, SENDECO and MIBGAS data.

The greater the share of renewables, the greater the decoupling between electricity prices and its main determinants, gas prices and ETS

DOES THE SHARE OF RENEWABLE HAS AN IMPACT ON THE PROBABILITY OF HAVING A LOW PRICE? (*)



(*) For this graph, the distribution of the residuals are plotted in two groups. The first group are the residuals when the share of green technologies is in α, and the second group are the residuals when the share is below all the α.
Source: BBVA Research from OMIE data.

- When the share of renewables is above 80%, the modal price is between 90% and 100% below that estimated from the traditional factors affecting electricity prices.
- This shows two effects of renewables. First, the expulsion of more expensive combined-cycles and the increase in hydro competitiveness, which is captured by the quadratic model, and second, the cases in which the price is set by renewables, which are not captured by the model, due to the decoupling between electricity prices and gas and ETS prices. The greater the penetration of renewables, the greater the probability of this second effect.

“Merit-order effect” in solar and wind unit revenues. Exogenous variables

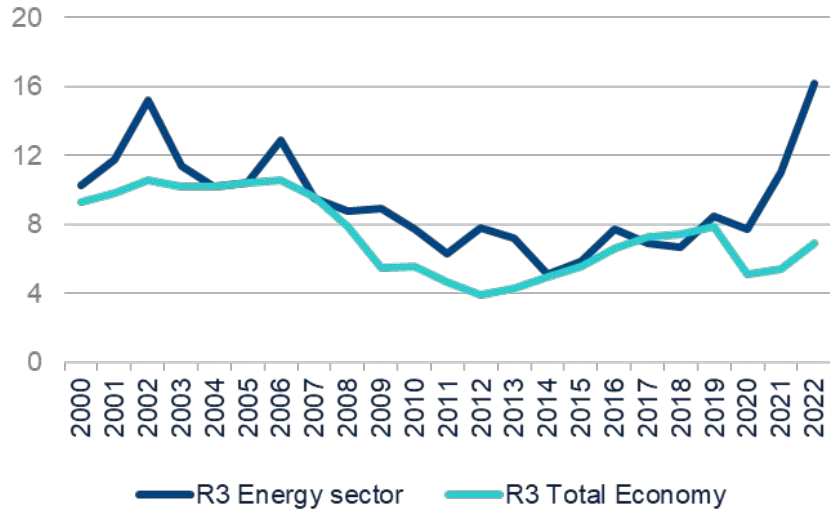
SUMMARY OF MAIN VARIABLES (GWH)

	Solar supply	Wind supply	Non-renewable supply
Min	5.9	16	24.1
25%	23.6	61.1	77.8
Median	34.5	90.5	108.7
Mean	44.4	106.5	130.6
75%	60.2	136.3	167.3
Max	137.4	353.5	411.4

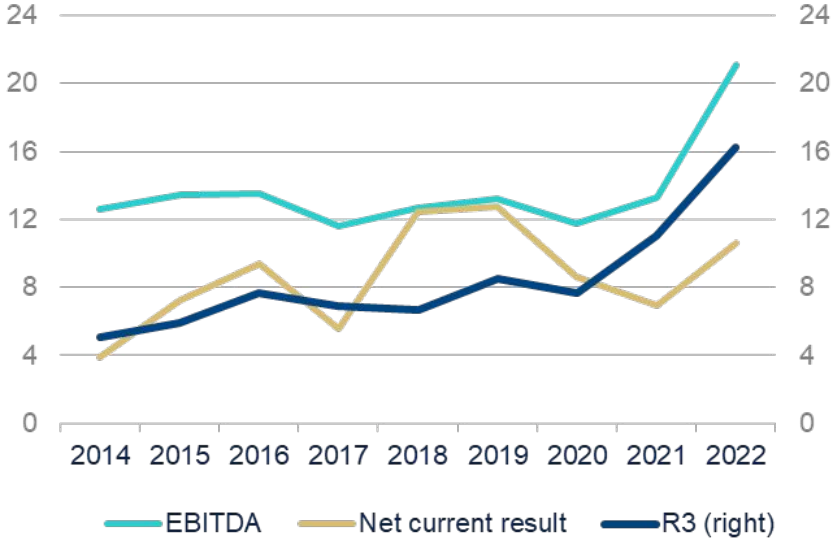
Source: BBVA Research from OMIE data

Energy companies' profits rose, driven by higher turnover

R3. ORDINARY RETURN ON EQUITY (FINAL BALANCE)
%



ENERGY SECTOR. NET CURRENT RESULT, EBITDA AND R3 MILLION EUROS AND %

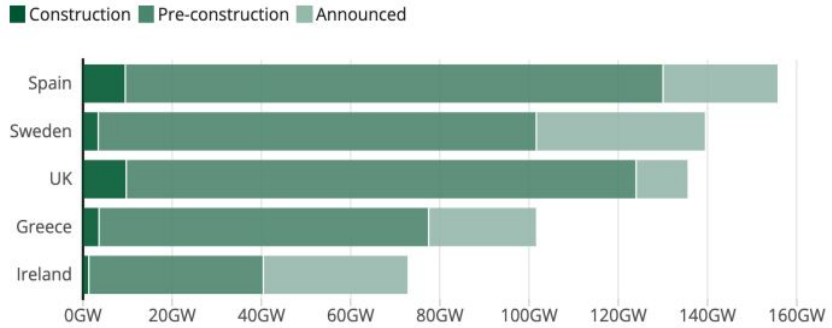


Source: BBVA Research from Bank of Spain data (Central Balance Sheet).

Spain leads Europe in utility-scale solar and wind potential, but permitting delays limit current capacity and future growth

UTILITY-SCALE SOLAR AND WIND CAPACITY IN TOP 5 EUROPEAN COUNTRIES

GW



Data includes solar project phases with a capacity of 20 megawatts (MW) or more and wind projects phases with a capacity of 10 MW or more.
SPAIN: "The recent glut of renewable energy proposals has exacerbated delays in Spain's already time-consuming permitting process, which can take up to five years to complete. This means that some prospective projects currently listed in GEM's database, even if successful, may not actually be commissioned before 2030."
Source: GEM-wind-solar-Spain-brief-June 2024.pdf; Methodology - Global Energy Monitor
(*) Less than one fifth of projects in Spain's permitting queue earlier 2022 received environmental and construction permits. Some 45 to 50% of solar projects in Spain were behind schedule because of environmental impact assessments, according to a Deloitte report. Reference: Spain's bulging solar pipeline heaps pressure on permitting.

- Spain already has 29.5 GW of utility-scale solar energy installed, and 7.8 GW under construction, with around 100 GW of additional utility-scale solar projects in pre-construction status.
- However, some prospective projects might not actually be commissioned due to time-consuming permitting progress process (to five years to complete). (*)
- It is also worth noting that solar power is not using all the installed capacity. It operates only 40% of the total hours of sunshine per year (1000 hours compared to 2500 sunshine hours per year on average).

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