



Report 2022

Spain

Earth, Water and Wind. Photo: Francisco Javier Lozano Cortés.

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In 2022, the power supply generated from renewable energy sources reached 42.2% of total power consumption in Spain. This contribution was 4.6% lower than the previous year, mainly due to a sharp decline in hydropower production as the total power demand decreased by 2.4%.

Throughout 2022, wind power was Spain's second largest electricity generation source, with a relative growth in power generation of 1%. According to the Spanish National Integrated Energy and Climate Plan 2021-2030 (NECP), the government is committed to reaching 20.43 GW of new wind capacity to meet the European targets for 2030. This will be the result of about 28.86 billion EUR (35.29 billion USD) in investment from 2022 to 2030.

The Spanish wind sector installed a total of 1.67 GW of new capacity in 2022 [1]. Wind power is the number one energy-generating technology on the Spanish peninsula, accounting for 25.2% of installed power capacity.

The Spanish government approved the first Offshore Wind Roadmap in 2021. It aims to kick-start the deployment of offshore wind so that up to 3 GW of capacity are operating by 2030. Considering Spain's

geography, it will all be floating offshore wind. Ports and shipyards across Spain already play a key role in the rest of Europe. The new Roadmap will stimulate the further development of Spain's floating wind supply chain.

National investments for wind-related R&D totalled around 16 million EUR (17.17 million USD) in 2022.

Highlight(s)

- Wind Power has the largest installed capacity (30 GW, 25% share) of the Spanish continental power system and the second largest share in electricity generation (22.1%).
- The government is committed to reaching a total wind capacity of 50 GW to meet European targets for 2030. This includes 3 GW of floating offshore capacity.
- Most new onshore wind projects are hybrid; many old wind farms will be hybridised with solar PV.

Market Development

Targets and Policy

At the end of 2019, the Spanish government announced its final draft of the National Integrated Energy and Climate Plan 2021-2030 (NECP) [3]. The plan presents ambitious measures to reduce greenhouse gas emissions (GHG) by 23% compared to levels in 1990 and to create a 28% share of renewable-generated power through electrification and transport. That plan established that the combination of all renewables will amount to 120 GW in total installed capacity by the end of 2030. This capacity will translate into a 74% share of renewable electricity generation and a 42% share of renewables in the final energy consumption.

This goal is anticipated to set Spain on track to achieve a 90% reduction in gross GHG emissions compared to 1990 by 2050. After which, Spain's power system is expected to operate on 100% renewable energy.

The NECP 2021-2030 proposed wind capacity growth is presented in the Table 2.

Progress and Operational Details

Spain installed 1,670 MW of new wind power capacity in 2022. These installations included 837 MW in Castilla La Mancha, 492 MW in Aragon, 105 MW in Castilla and Leon, 73 MW in Cataluña, 53 MW in the Canary Islands, 50 MW in Navarra, 40 MW in Asturias and 20 MW in Andalucía.

The land-based wind power capacity increased by 1,670 MW, comprising 46 wind farms, which include 395 wind turbines. This brought the total capacity in Spain to 29,827 MW in 2022. Currently, 22,042 wind turbines are installed in 1,345 wind farms in more than 800 municipalities, occupying only 0.017% of Spanish territory. The average rated power of the installed wind turbines in 2022 was 4.23 MW.

Wind-based electricity generation

Table 1. Key National Statistics 2022: Spain.

Total (net) installed wind power capacity	29,827.81 GW
Total offshore capacity	0,005 GW
New wind power capacity installed	1,670 GW
Decommissioned capacity (in 2022)	GW
Total electrical energy output from wind	61,069 TWh
Wind-generated electricity as percent of national electricity demand	22.2%
Average national capacity factor	23.4%
Target (by 2030)	50.26 GW
National wind energy R&D budget	16 million EUR (17.17 million USD)

Table 2. NECP 2021-2030 proposed wind capacity growth.

Capacity MW/Year	2015	2020	2025	2030
Wind Energy (on & offshore)	22,925	27,968	40,258	50,258

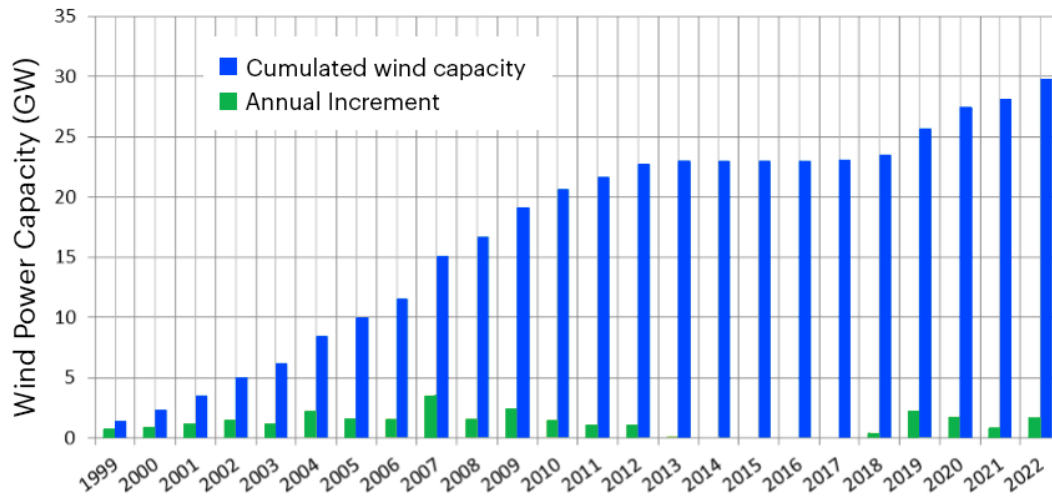


Figure 1: Annual and cumulative installed wind power capacity in Spain (Source: AEE).

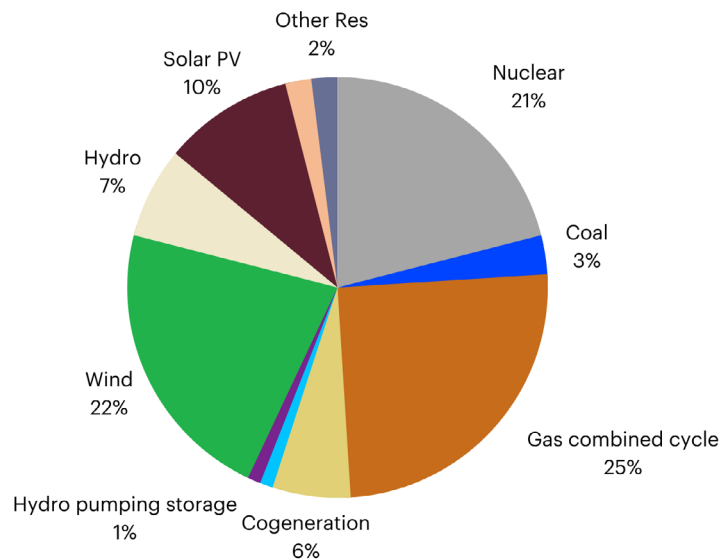


Figure 2: Sources of the 2022 power supply in Spain (Source: AEE).

was responsible for 61.07 TWh/year, representing 22.2% of total electricity generation. Although the total electricity demand for 2022 decreased by 2.4%, wind-based electricity generation increased by 1% compared with 2021. Wind energy now accounts for Spain's second-largest electricity generation source, closely following gas combined cycle generation (Figure 2). Gas generated 60.8% more electricity than in 2021 for two reasons. Firstly, due to the introduction of the so-called "Iberian Exception", which introduced a cap on the price of electricity generated using natural

gas in combined cycle power plants in the Iberian daily energy auctions. Secondly, a significant increase in gas exports which created the highest recorded exchange balance of 19.8 TWh.

In Spain, the evolution of energy needed to cover the different ancillary services is increasing. Over half of the wind energy capacity is already integrated into the grid ancillary services. In 2022, wind energy provided 10.1% of the required energy balance. This represents a significant increase compared to previous years, participating

in replacement reserves, real-time technical restrictions (curtailments) and tertiary control. Wind energy is the only renewable source, excluding large-scale hydro, that actively engages in ancillary services, demonstrating its ability to contribute to the security of the power system.

In 2022, wind technology provided replacement reserves to the power system of 202.4 GWh/year upward and 423 GWh/year downward, representing an increase of 44.6% and 29.5%, respectively, compared to 2021. The real-time technical

constraints (curtailments) had a smaller effect on wind energy production than the previous year, with 286.9 GWh/year compared to 288.8 GWh/year in 2021. Wind energy represented 38.7% of the total downward real-time technical restrictions. Finally, wind energy provided tertiary control of 159.5 GWh/year upwards and 203.5 GWh/year downwards, representing 7% of the total tertiary control balancing power upwards and 13.4% downwards.

Matters Affecting Growth and Work to Remove Barriers

The 2022 Spanish wind auction was significantly impacted by increasing pressure on the cost of wind technology as well as design flaws. This resulted in only 46 MW out of 1.5 GW of awarded capacity. Mainly, the low cap caused by inflation on the cost of new wind turbines was not taken into account and produced the unexpected result of the auction.

The offshore wind project is planned to commence in Spain in 2023: The Spanish Maritime Spatial Plan (MSP) was adopted on the 28th of February 2023, allocating 5000 km². However, regulations are still pending. New offshore wind testing facilities are under development (Specific Recovery Funds).

While onshore wind has already been experiencing non-compensated curtailment, 2022 saw more of them: 700 GWh of renewables curtailment, including 352 GWh of solar PV generation.

RD&D Activities

National RD&D Priorities and Budget

In September 2020, the Spanish Science, Technology, and Innovation Strategy 2021-2027 [5] was approved with the main objective of doubling the amount of public and private investment in RD&D&I (Research & Development & Innovation) to 2.12%

of GDP by 2027.

The Spanish government considers wind energy a national priority. R&D activities primarily focus on land-based applications, including increasing O&M cost competitiveness, extension-of-life strategies for wind farms, optimised manufacturing processes, etc. Offshore wind R&D activities are increasing, especially for floating applications. National investments in wind energy R&D amounted to nearly 13.4 million EUR (14.37 million USD) in 2022.

National Research Initiatives and Results

The main topics of the Low TRL Research Projects funded by the Spanish Energy Agency AEE in 2022 are:

- Floating offshore wind power.
- Environmental impact: Acoustic noise, Recycling (Blades, tower).
- Predictive maintenance.
- Wind resource assessment in complex terrains.

In 2022, there were still several calls under evaluation. Some projects have already been funded, such as the following:

- Assessment of the acoustic impact of wind and tidal farms on marine life by the Polytechnical University of Madrid.
- Impact of sound on marine ecosystems from offshore wind energy generation by Las Palmas de Gran Canaria University.
- Impact of sound on marine ecosystems from the generation of offshore wind energy by the Consortium for the design, construction, equipment, and exploitation of the Canary Islands oceanic platform.

Regarding High TRL Research Projects, the main topics are:

- Maintenance of floating wind farms.
- Wind turbine vibration control.
- Innovative procedures for design, manufacturing, and installation of components (Towers, platforms).

In 2022, the Spanish innovation agency, CDTI, financed the following 13 projects, totalling around 13 million EUR (13.94 million USD):

- New yaw energy reserve system up to 375 KVA, by INGETEAM POWER TECHNOLOGY.
- New technologies for the blade (NUTELA), by SIEMENS GAMESA RENEWABLE ENERGY INNOVATION & TECHNOLOGY SL.
- Self-tuning optimised control system for efficiency and lifetime enhancement of wind turbines, by ADAPTIVE PREDICTIVE EXPERT CONTROL ADEX SA.
- New high-power wind turbine platform with a larger rotor diameter for moderate wind sites, by NORDEX ENERGY SPAIN SA.
- New stator segments for electric generators for offshore wind turbines – GEMA, by GAMESA ELECTRIC SA.
- Development of a new floating building platform optimised for floating offshore wind turbines with concrete-based platforms, by COBRA INFRAESTRUCTURAS HIDRAULICAS S.A.
- New solutions for structural design excellence of wind turbine towers, by GRI R&D ENGINEERING SL.
- WIND-BOS: Innovative floating offshore platform spar type for Korean water, by BLUENEWABLES SL.

- New enabling technologies for tower building and installation for the next generation of wind turbines for low wind production, by NABRAWIND TECHNOLOGIES SL.
- Wind power concrete tower with multidirectional variable pre-stressing system, by WINDTECH-NIC ENGINEERING SL.
- Digital integrated platform for floating wind farm operation and maintenance (3 different

ones, developed by: HI IBERIA INGENIERIA Y PROYECTOS SL, SEAPLACE, S.L., and SUBSEA MECHATRONICS SL).

Test Facilities and Demonstration Projects

There are five marine test facilities. The two of them in operation include BIMEP in the Basque Country coast and PLOCAN in Gran Canaria island. The three under development include PLENCAT in Catalonia,

Granadilla Lab in Tenerife island and Langosteira Platform in Galicia. EU-specific recovery funds finance these facilities.

There are more than 14 prototypes of floating offshore wind platforms under different stages of development in Spain: NAUTILUS FS by Nautilus Consortium, WINDCRETE by UPC and COREWInd, SATH by SAITEC, TLPWind by Iberdrola, WHEEL by Esteyco, CROWNBUOY by Seaplace and Brezo Energy, W2POWER by

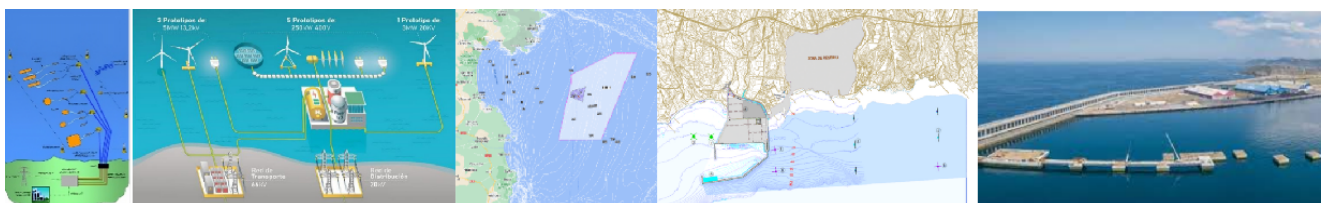


Figure 3: Illustrations and photos of the five marine test facilities (From left to right: BIMEP, PLOCAN, PLENCAT, Granadilla and Langosteira).



Figure 4: Illustrations and photos of the most relevant prototypes of floating offshore wind platforms.

EneOcean, FIROVI by Firovi, PIVOT-BUOY by X1Wind, TRIWIND by Berdi Power Group, MENHIR by Dragados, IHCantabria and PHECOR, S-BOS and CT-BOS by Acciona Bluenewables, and HIVE WIND by

Sener and Amper.

The most advanced platform is the DEMOSath prototype which will be ready to be tested in the BIMEP

facility in 2023 with a 2 MW wind turbine.

Collaborative Research

Spain is participating in the following technological collaborative tasks:

- Task 11: Base Technology Information Exchange.
- Task 25: Power Systems with Large Amounts of Wind Power.
- Task 30: OC6 - Offshore Code Comparison Collaboration, Continued with correlation and uncertainty.
- Task 34: WREN Environmental Assessment and Monitoring.
- Task 37: Wind Energy Systems Engineering.
- Task 41: Enabling Wind to Contribute to a Distributed Energy Future.
- Task 46: Erosion of Wind Turbine Blades.
- Task 48: Airborne Wind Energy.

Impact of Wind Energy

Renewable technologies produced 42.2% of all electricity generated in Spain in 2022, which accounted for a slight reduction due to the lack of hydropower. In this regard, it is noteworthy that wind power generation is already the leading source of renewable electricity generation in Spain, with a 22.2% share of total demand nationwide. In 2022, the average hourly electricity market price was 204.79 €/MWh (216.31 \$/MWh), compared to 126.29 €/MWh (133.40 \$/MWh) in 2021, indicating a significant increase.

Environmental Impact

According to OTEA [4], in 2022, wind energy offset the emission of 32 million tonnes of CO₂, which accounts for 10.2% of total CO₂ emissions in 2022, equal to 305 million tonnes of CO₂.

Economic Benefits and Industry Development

The Spanish wind sector employs 32,000 people annually. More than 250 companies work in 16 of the 17 Autonomous Communities in Spain. Wind Energy, directly and indirectly, contributes to 0.49% of the GDP. The sector exportations accounted for around 1.75 billion EUR (1.99 billion USD) in 2022, making it the third largest globally [2].

The main wind turbine suppliers were Siemens Gamesa ER, Vestas, GE RE, Nordex-Acciona WP and Enercon. 100% of the entire supply chain is available in Spain, constituting a manufacturing capacity of 4,000 MW/year. Spain leads technological development, rating as the sixth country in the world for wind power patents and the first in the development of floating offshore wind prototypes.

The total wind energy sector R&D investments accounted for around 13.4 million EUR (14.37 million USD), and the resulting patents place Spain third in Europe and sixth globally.

In 2022, wind power became a pivotal element in capping the price of electricity in Spain. According to the AEE figures [2], Spanish consumers saved more than 8.25 billion EUR (9.85 billion USD) on electricity bills. The reducing effect of wind power in 2022 was 31.25 €/MWh (33.53 \$/MWh). In other words, without wind energy generation, the average price of electricity in 2022 would have increased by 18% from 167.61 €/MWh (179.85 \$/MWh) to 198.86 €/MWh (213.48 \$/MWh).

Next Term

The Spanish coastline spans 7,661 km – this territory offers the country the opportunity to take advantage of offshore wind energy. Due to the characteristics of the Spanish coastline, the most suitable offshore wind technology is floating offshore wind.

In addition to the continued development of onshore wind power to reach the NECP 2021-2030 goals, Spain aims to take advantage of their vast coastline through the deployment of floating offshore wind farms. The planned offshore wind capacity of 3 GW by 2030 is projected to consist only of floating turbines, mainly in the Canary Islands, the north-western coast of Galicia and north-eastern coast of Catalonia.

Finally, between 10 and 15 GW of wind capacity is expected to be re-powered during the next decade.

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