Report 2021

Spain

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Renewable sources-based power supply in Spain reached 46.7% of total power consumption in 2021 (Total power demand increased by 2.5%).

Throughout 2021, wind power was Spain's largest source of electricity generation, with a relative generation growth of 2.7%. According to the Spanish National Integrated Energy and Climate Plan 2021-2030 (NECP), the government is committed to increasing the wind capacity to 50 GW, which means about 28.86 billion EUR (35.29 billion USD) to meet European targets for 2030.

The Spanish wind sector installed 842.61 MW during 2021 [1]. Wind power has become in Spain the number one technology (25.7%) regarding installed power capacity on the Spanish peninsula. Spain was the number seven in Europe in new investments with 1.5 billion EUR (1.83 billion USD) investment decisions in new onshore wind farms.

The Spanish government approved the first Offshore Wind Roadmap in 2021. It aims to kick-start the deployment of offshore wind with a view to having up to 3 GW operating by

Table 1. Key National Statistics 2021: Spain

Total (net) installed wind power capacity	28,157.81 GW
Total offshore capacity	0,005 GW
New wind power capacity installed	842.61 GW
Decommissioned capacity (in 2021)	GW
Total electrical energy output from wind	60.46 TWh
Wind-generated electricity as percent of national electricity demand	23.3%
Average national capacity factor	24.8%
Target (by 2030)	50,26 GW
National wind energy R&D budget	12 million EUR (16,56 million USD)

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

2030. Given 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 12 million EUR (16.56 million USD) in 2021.

Highlight(s)

- Wind Power is the first technology (25.7%) in installed power capacity and, for the first time, also became the largest source of electricity generation (23.3% of total).
- First Offshore Wind Roadmap approved: 3GW Floating Offshore Wind by 2030.
- The average rated power of the 2021 installed wind turbines was a record 5.4 MW.
- The first hybrid wind farm (32 MW) with batteries (5 MW, 1 hour) has been carried out.

Market Development

Targets and Policy

By the end of 2019, the Spanish government announced its final draft of the National Integrated Energy and Climate Plan 2021-2030 (NECP) [3], raising the country's ambitions for greenhouse gas emission (GHG) reduction to 23% compared to 1990 level and 28% renewables share through electrification and transport. That plan established that the combination of all renewables will amount to 120 GW by the end of 2030. This capacity will translate into 74% renewables share in electricity generation and 42% share of renewables in the final energy consumption.

This goal should set Spain on track to achieve a 90% reduction in gross GHG emissions compared to 1990 by 2050. By then, 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 on page 3:

Progress and Operational Details

Spain installed 842.61 MW of new wind power capacity in 2021. These installations included 207 MW in Aragon, 116 MW in Castille and Leon, 139 MW in Asturias, 69 MW in Castille La Mancha, 28 MW in Galicia, and 43.5 MW in Andalusia, 7 MW in Navarra, and 69 MW in the Canary Islands.

Land-based wind power capacity increased from 842.61 MW to 28,157 MW in 2021, comprised of 1,298 wind farms, which include 21,574 wind turbines. The average rated power of the 2021 installed wind turbines was 5.43 MW. Wind-based electricity

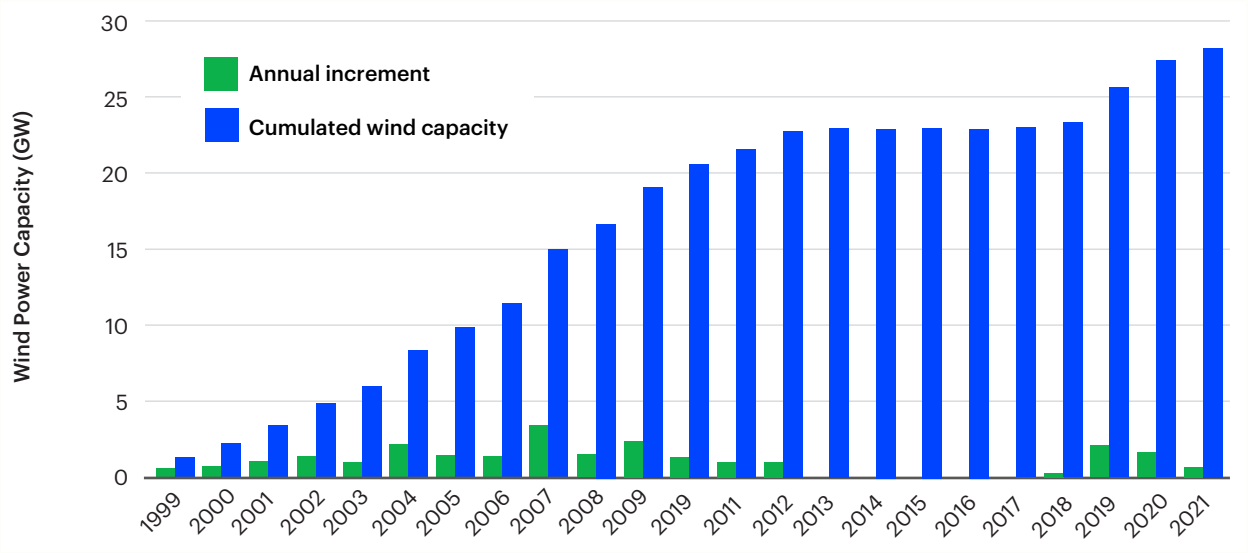

Figure 1: Annual and cumulative installed wind power capacity in Spain (Source: AEE).

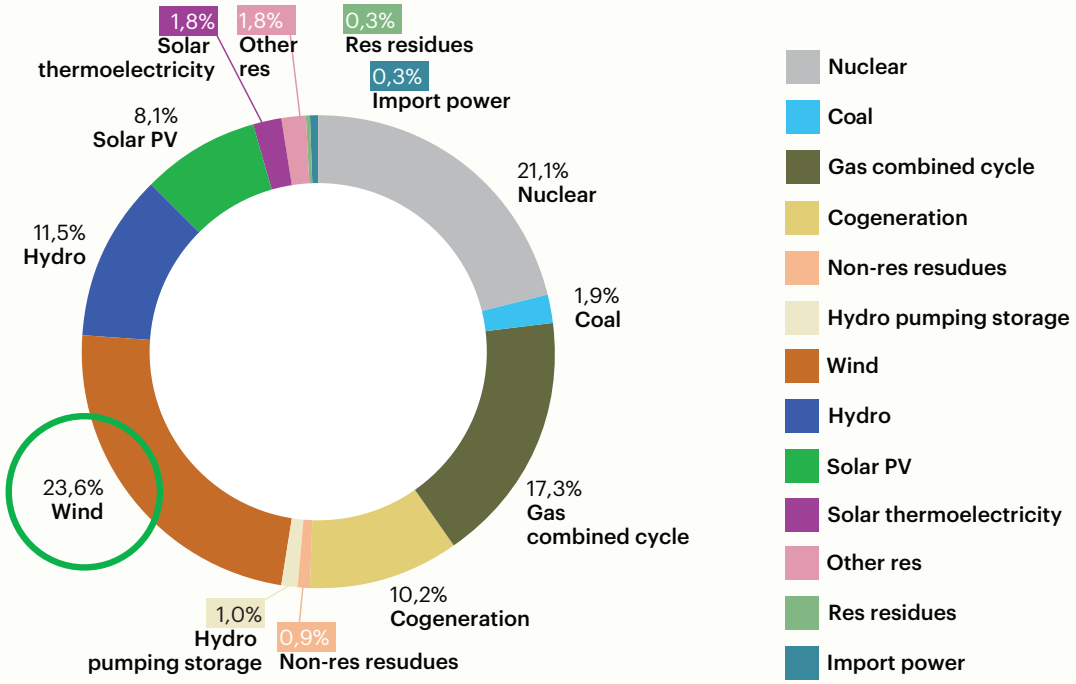

Figure 2: Sources of the 2021 power supply in Spain (Source. REE).

generation was responsible for 60.46 TWh p.a., representing 23.6% of total electricity generation (which experimented with an increase of 2.5%). Wind-based electrical generation increased by 1.2% and became the largest source of electricity generation in Spain for the first time (Figure 2).

Spain already integrates wind power into the grid ancillary services. In 2021, wind technology has covered around 28% of the overall upward as well as around 23% of the overall downward measured net deviations markets [4].

With the new wind power auctioned in January and October of 2021, 3,256 megawatts have been approved (998 MW in January at 25.31 EUR/MWh (28.80 USD/MWh) and 2,258 MW in October at 30.18 EUR/MWh (34.28 USD/MWh)). Those Wind farms must be put into operation

before October 2024.

Three new records were achieved by wind power in 2021:

- On December 8, wind power surpassed 20,000 MW of instantaneous generation for the first time in history (20,130 MW at 1:34 p.m.).
- On December 8, a new maximum daily wind power peak was set at 416 GWh.
- On December 29 at 3:03 am, wind power covered 83.6% of peninsular demand.

Matters Affecting Growth and Work to Remove Barriers

At the beginning of 2020, Spain had a backlog of more than 430 GW worth of requests for grid access. The Government considers that some of these projects are speculative ventures given their immaturity and the fact that around 60% of grid access holders have not applied for a corresponding connection permit. These circumstances make it more expensive to realise sound projects that will really move investment and create jobs. To help solid projects get ahead, the Government set up in June 2020 a Royal Decree Law 23/2020, which sets deadlines for each milestone in the permitting chain that project developers must meet to get the next permit. Failing that, any granted permits will expire automatically, and deposited financial guarantees will be lost. In all, developers have five years to complete the whole process. Within three months following the RDL's entry into force, permit holders can exit the chain and claim their deposits. In the meantime, the RDL imposes a moratorium on new requests for grid access until these permits are further regulated. New regulation on access requires developers to present projects in mature stages and previous studies.

The RD 1183/2020 was approved in December 2020 to face up to the new reality of the power sector by the regulation of the access and connection to the electricity transmission and distribution networks with the intention of adapting to EU requirements.

Taking into account these two laws that have already been approved, the lack of harmonisation of the procedures for obtaining permits in the different Autonomous Communities, and the limitations of the administration to manage a large number of requests and claims over time, growing concern from developers is anticipated regarding project due dates.

A total budget of up to 1.32 billion EUR (1.5 billion USD) in order to promote self-consumption and storage of renewable energy was approved in June 2021. Wind energy is explicitly included in some of the proposed programs. In the case of small wind power, grants range from 20% to 70%, depending on the type of installation and user.

RD&D Activities

National RD&D Priorities and Budget

In September 2020, the Spanish Science, Technology, and Innovation Strategy 2021-2027 [7] was approved with the main objective of doubling the amount of public and private investment in RD&D 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: increasing O&M cost competitiveness, extension-of-life strategies for wind farms, optimised manufacturing process, etc. Offshore wind R&D activities are increasing, especially for floating applications. National investments in wind energy R&D amounted to nearly 12 million EUR (16.56 million USD) in 2021. This budget is significantly lower than the previous years.

National Research Initiatives and Results

According to the EU Implementation Plan, the main targets of Spanish R&D are the reduction of the LCoE for onshore and offshore wind turbines by improvement of the performances of the entire value chain and the development of cost-competitive integrated wind energy systems, including substructures which can be used in deeper waters (>50m) at a maximum distance of 50 km from shore with an LCoE of less than 0.12 EUR/kWh (0.14 USD/kWh) by 2025. In this sense, several R&D projects have been funded, such as:

- Nanofluids optimised to increase the production of electrical energy with wind turbines developed by the University of Santiago de Compostela.
- Wind/PV/Gasification hybrid system with H2 Storage developed by the University of Malaga.
- Mesh generation for wind power forecasting was developed by the Barcelona Supercomputing Center (BSC).
- Principles and applications of soil mechanics for the anchorage of marine renewable energy facilities. Developed by the International Centre for Numerical Methods in Engineering (CIMNE).

In 2021 the Spanish innovation agency CDTI has financed the following 10 projects, totalising nearly 10 million EUR (11.38 mill USD)

- Blades Acoustic Monitoring System developed by ALTRAN Innovation S.L.
- Innovative Technologies in Nacelle developed by Siemens Gamesa Renewable Energy innovation & Technology S.L.
- Development of a Power Conversion System in DFIG Topology for Turbines up to 7 MW developed by Ingeteam Power Technology S.A.
- Condition Monitoring and Intelligent Operation & Maintenances Technologies toward High-Reliability Wind Turbine developed by Ingeteam Power Technology S.A,

Figure 3: Left: DemoSATH floating offshore wind platform (Bilbao Port, Spain). 2 MW Full scale prototypes. *(Credit: SAITEC)* Right: Pivotbuoy. Floating offshore wind platform 1:3 partial scale prototype (Las Palmas Port, Spain). *(Credit: X1 Wind).*

- Intelligent Manager for the Maintenances of Wind Turbines Blades developed by GIDES Wind S.L.

- Innovative Substructures and Installation Progress in Deep Water to Reduce the Cost of Offshore Wind Energy developed by Nabrawind Technologies S.L., TETRACE 824 S.L., ISATI Engineering Solutions S.L., and INGECID Investigacion y desarrollo de Proyectos S.L.

- Innovative Tubular Anchorage System for TLP Marine Floating Structures developed by Bluenewables S.L.

Test Facilities and Demonstration Projects

However, the main research activity has been focused on floating offshore wind prototypes: Two of the most advanced projects are the DemoSATH Project, developed by SAITEC Offshore Technologies, with a full scale 96m diameter 2MW wind turbine based on hybrid lines for the mooring system and drag anchors, which will be tested at BIMEP Test Facility (85 m sea depth) in the Basque Country in 2022; or the PivotBuoy concept, developed by X1 Wind, with a partial scale 1:3, 29m rotor diameter 225 kW downwind wind turbine with 3 TLP single point mooring and gravity anchors. This prototype was assembled at Las Palmas Port in late November and will be tested at PLOCAN Test Facility 50 m sea depth in the Canary Islands in 2022.

Finally, as demo project just to mention that the first hybrid wind farm (32 MW) with batteries (5 MW, 1 hour) has been carried out in 2021 developed by Iberdrola.

Collaborative Research

Spain serves as Operating Agent for IEA Wind TCP Task 31: Wakebench: Benchmarking Wind Farm Flow Models. Spain also participates in:

- Task 11: Base Technology Information Exchange
- Task 25: Power System with Large Amounts of Wind Power
- Task 30: Offshore Code Comparison Collaboration, Continuation with Correlation (OC6)
- Task 34: Working Together to Resolve Environmental Effects of Wind Energy (WREN)
- Task 36: Forecasting for Wind Energy
- Task 37: Systems Engineering in Wind Energy
- Task 40: Downwind Turbine Technology
- Task 41: Enabling Wind to Contribute to a Distributed Energy Future

Impact of Wind Energy

In 2021, electricity demand in Spain recovered gradually after the impact of the pandemic and grew by 2.5% compared to 2020. In terms of generation, renewable production reached an all-time high of 119,733MWh, a 46.7% share of the electricity generation mix in 2021 (44% in 2020).

In this regard, it is noteworthy that wind power generation is already the leading source of electricity generation in Spain, with a 23.3% share of total production nationwide. The average electricity price in December was €239.16/MWh, a new all-time high, with an increase of 24% compared to November and 470% compared to December 2020. In 2021, the average hourly price of 126.29 €/MWh, compared to 33.95 €/MWh in 2020, shows a significant increase in prices and their volatility in 2021.

Environmental Impact

According to OTEA [5], during 2021, wind energy avoided the emission of 32 million tons of CO2 (11.3% of the 2021 total CO2 emissions (288 Mill T CO2).

Economic Benefits and Industry Development

The Spanish wind sector employs 27,500 people annually. More than 250 companies work in Spain in 16 of the 17 Autonomous Communities. Wind Energy, directly and indirectly, contributes 3 billion EUR to the GDP, which represents 0.30%. The sector exportations account for around 1.75 billion EUR (1.99 billion USD) in 2021, being in the third position in the world. [2]

There are currently installed 1,298 wind farms in more than 800 municipalities.

The main wind turbine suppliers were Siemens Gamesa ER, Vestas, GE RE,

Photo: Juan Mayobre/Unsplash

Nordex-Acciona WP, and Enercon, being 100% of the entire supply chain available in Spain.

The total wind energy sector R&D investments accounted for around 12 million EUR (16.56 million USD), and the resulting patents place Spain in third place at a European level and in sixth place at a world level.

Wind energy benefits the electricity markets, lowering the high prices observed recently. According to AEE [2], the variations in prices have become more pronounced: on the days with the highest wind power generation, minimum average electricity prices of around 3 EUR/MWh (3.4 USD/MWh) were reached. And when wind generation was lower, higher prices are observed. The price-reducing effect of wind generation in 2021 has been 18.42 EUR/MWh. The cumulative savings achieved by wind power in 2021 amounts to 4,757 million EUR (5,413 million USD). This result is obtained from the value of average instantaneous wind power generation, which in 2021 was 6,736 MW, to which corresponds an average price in its band of 112.34 EUR/MWh (127.84 USD/MWh). Comparing it with the value that would be obtained if there were no wind power generation (130.76 EUR/MWh) (148.8 USD/MWh), the aforementioned reduction effect is obtained, which must be multiplied by the total generation of the system to obtain the annual savings.

Next Term

In Spain, there are 7,661 km of coastline. An extension that 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.

For this reason, in addition to the necessary continued development of onshore wind power to commit to the NECP 2021-2030 goals, the future is the deployment of floating offshore wind farms. The Spanish government has set 3 GW as a target in the offshore wind roadmap.
Spain can lead the development of this technology thanks to its research and innovation capabilities, its industrial capacity, its geographical position, and its competitiveness.
The development of floating offshore wind farms takes advantage of new locations far from the coast, with capacity factors that exceed 4,000 equivalent hours and that reduce visual and environmental impact.

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