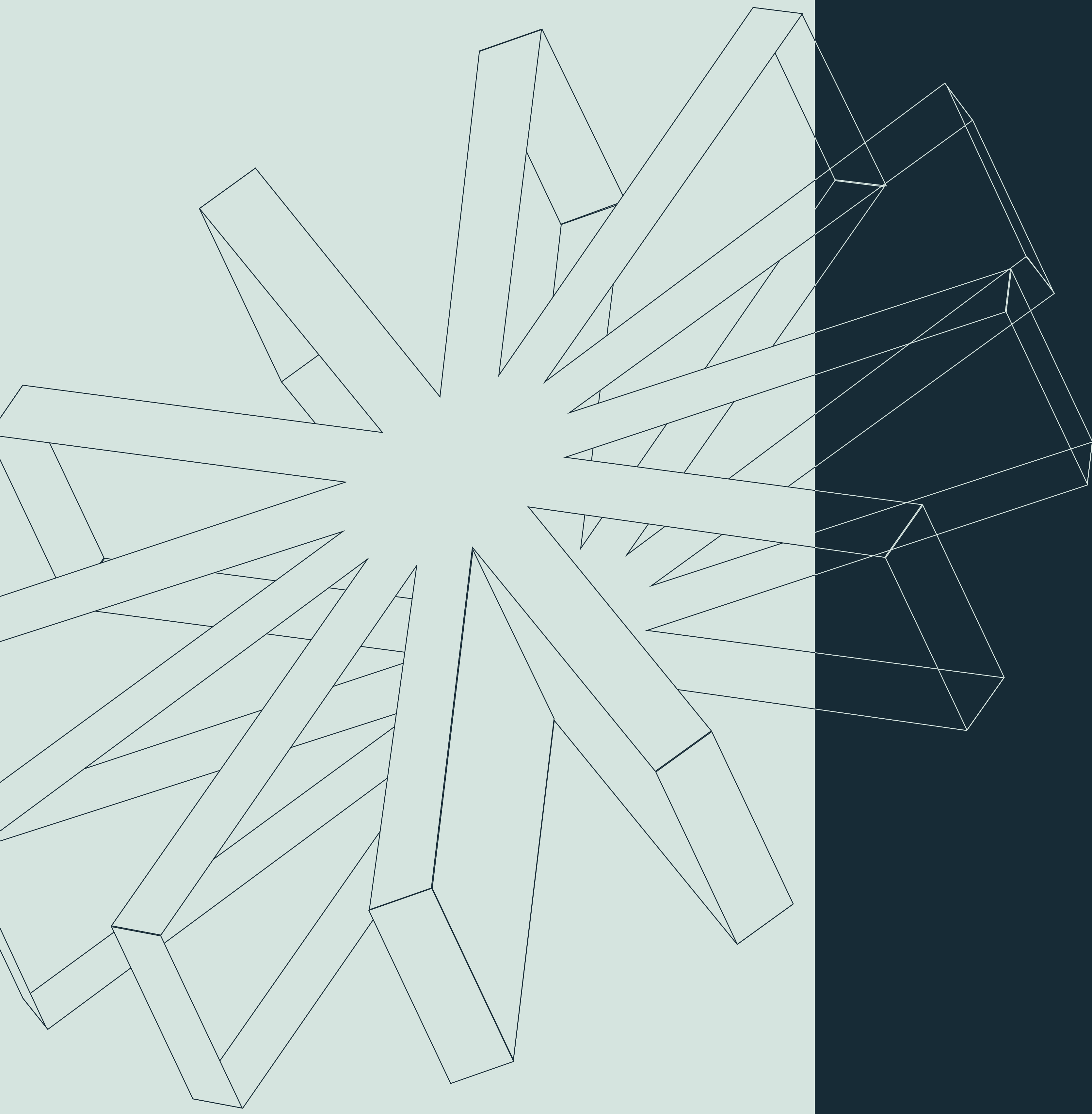

The Energy system in Spain and its transition

November 2025

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European Climate Foundation

This report has been prepared for **alinnea** by Juan Requejo Liberal, a specialist in Planning and Development.

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alinnea is a climate Think & Action Tank based at IE University and supported by the European Climate Foundation (ECF).

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Cite as: Fundación Instituto de Empresa (2025). The energy system in Spain and its transition. Sector Overview Series. Report prepared for alinnea by Juan Requejo Liberal.

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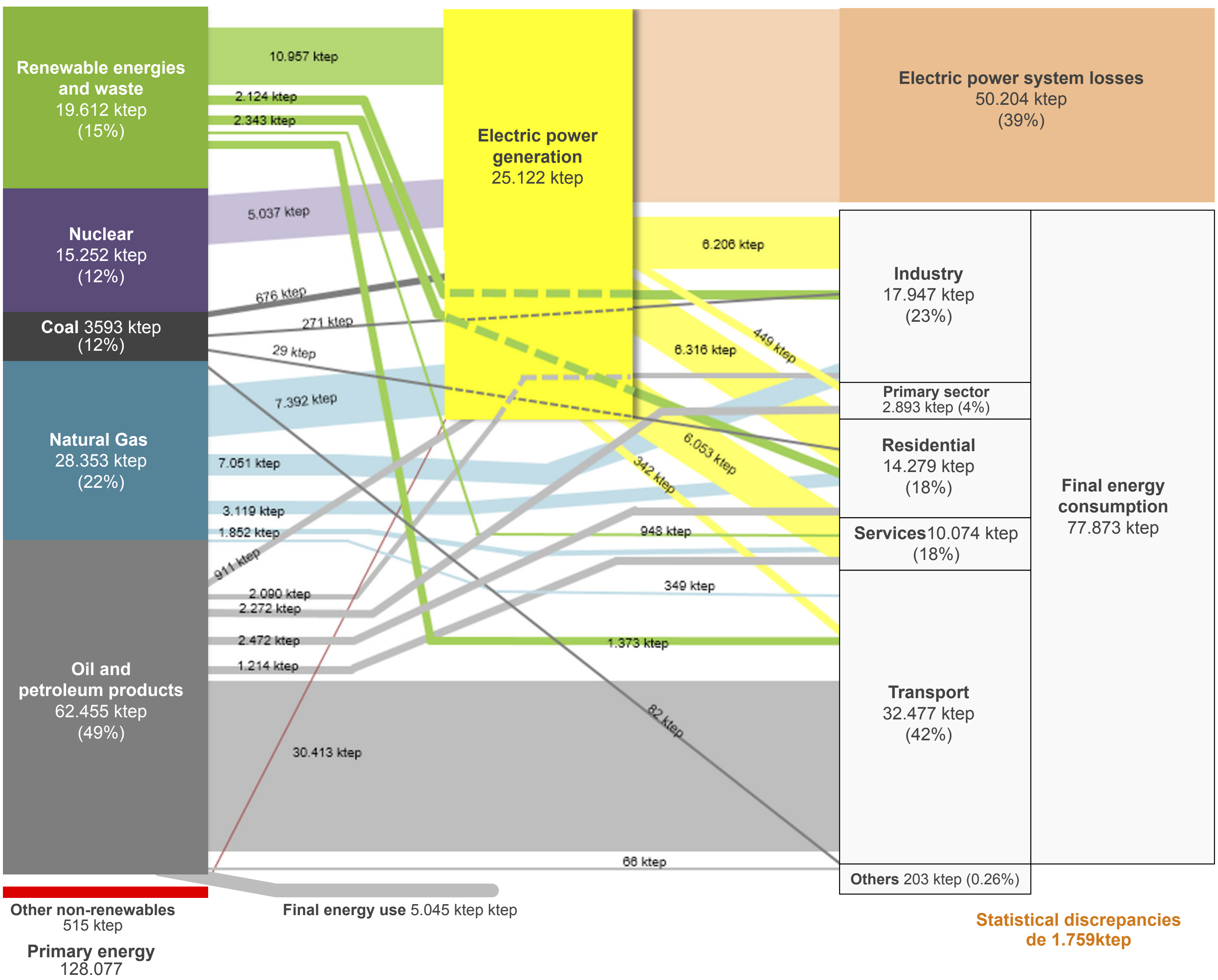
1 Spanish energy system

The Spanish energy system is summarized very adequately in this diagram, which was developed using methodology from the Lawrence Livermore Institute in the US. This diagram shows the central role of fossil fuels, especially oil, as the primary energy source for transportation. Secondly, it shows that electricity plays a secondary role in the system and that the industry is not sufficiently electrified. Electrification is the necessary vector for introducing renewables into the system, which, despite their spectacular development, only contribute 15% of the primary energy that sustains the country and 25% of the final energy.

Spain's Energy Balance (2022)



Source: EUROSTAT. Energy Balance of Spain. Secretariat of State for Energy (Spain)

2 Energy transition policy objectives

The energy transition policy aims to transform the current energy model—based on fossil fuels—into a more decarbonized one, with greater participation from renewable energies and less environmental impact. This transition involves a series of structural changes in energy production, distribution, and consumption, along with the implementation of several instruments to achieve these objectives.

The framework for climate and energy policy in Spain is determined by international agreements under the United Nations Framework Convention on Climate Change—particularly the Paris Agreement—and policies agreed upon within the European Union, guided by the goal of climate neutrality by 2050 and a radical change in external dependence on fossil fuels. European policy has the key benefit of reducing the cost of purchasing large quantities of fossil fuels from abroad and reducing the system's vulnerability to uncontrollable external factors.

Law 7/2021 of May 20 on Climate Change and Energy Transition introduces the legal basis to ensure Spain's compliance with the objectives of the Paris Agreement and facilitate the decarbonization of the economy, raising these international commitments to the legislative level. This law includes the Integrated National Energy and Climate Plans (PNIEC) and the Long-Term Decarbonization Strategy 2050 as strategic planning instruments to address the energy transition.

In this way, international commitments and the European legislative framework led to the necessary adoption by Spain of minimum targets and the implementation of a set of additional policies and measures to achieve the established objectives, in addition to taking advantage of the social, economic, and environmental opportunities of this process.
In 2021, the Council of Ministers approved the 2021-2030 National Integrated Energy and Climate Plan (PNIEC 2020), at the proposal of the Ministry for Ecological Transition (MITECO), for submission of the draft to the European Commission. However, since the adoption of the PNIEC 2021-2030, numerous legislative proposals have been presented and approved at the European level, each successively more ambitious in relation to climate change objectives (European Climate Law, "Target 55," and "REPowerEU" packages), resulting in the following targets currently agreed upon at the European level for 2030 (EU):

- 55% reduction in greenhouse gas (GHG) emissions compared to 1990 for the EU.
- 42.5% of renewables in gross final energy consumption, with an additional indicative supplement of 2.5% that would allow 45% to be achieved.
- 38-40.5% improvement in energy efficiency in final energy and primary energy, respectively, compared to the 2007 baseline scenario.
- 15% electricity interconnection between Member States.

Due to these changes in the European and international context, the **PNIEC has been updated** (recently approved by Royal Decree 986/2024 of September 24), and the targets have been revised upwards so that the new version of this plan includes the following set of main targets:

- To reduce greenhouse gas emissions from the Spanish economy by at least 32% in 2030 compared to 1990. Below the European target.
- Achieve a penetration of renewable energy in final energy consumption of at least 48% by 2030. Above the European target.
- Achieve an electricity system with at least 81% of generation from renewable energy sources by 2030.
- Improve energy efficiency by reducing primary energy consumption by at least 39.5% compared to the baseline in accordance with EU regulations. In line with the European target.
- Reduce energy dependence to 50%.
- 19 GW of self-consumption.
- 22.5 GW of storage.

TARGETS		PNIEC 2023
GENERAL	Reduction in GHG emissions compared to 1990	32
	Reduction in GHG emissions compared to 2005 – ETS sectors	-
	Reduction in GHG emissions compared to 2005 – Diffuse sectors	-
	Percentage of renewables in electricity generation	81
	Number of electric vehicles	5.5 million
	Number of renovated homes	1,377,000
	Total renewable energy capacity in the energy mix	Total: 214 GW Renewable: 160 GW
	Percentage of renewables in final energy consumption	48
	Energy efficiency. Reduction in primary energy consumption	- 39.5
	Energy efficiency Reduction in final energy consumption	-43
	Energy Dependency	50
TRANSPORT	Reduction in intensity of GHG emissions from transport	-
	Percentage of renewables in the transport sector	28%
	Combined percentage of RFNBO + Advanced bios and biogas from Annex IX Part A	17.26
INDUSTRY	Annual increase in renewable energy in industry	2.14% (2021-2025) 2.97% (2026-2030)
	Percentage of RFNBO** on hydrogen in industry	74
BUILDING, HEATING, COOLING	Final energy from renewables in buildings	67.59
	Annual increase in percentage of renewables in heating and cooling	1.42% (2021-2025) 2.36% (2026-2030)

*** RFNBO: Combustibles renovables de origen no biológico*

Table: PNIEC targets for 2030 in the current 2023 version
Source: Update of the PNIEC 2030 (MITERD, 2024)

To achieve these ambitious targets, renewable energies must contribute 81% of electricity generation in 2030 (compared to the 74% forecast in the previous PNIEC), with a special focus on self-consumption in different areas, which, driven by recent regulatory changes and the Recovery, Transformation, and Resilience Plan (PRTR), has set a target of 19 GW by 2030. In addition, the goal of integrating renewables into the electricity system requires an increase in energy storage to 22.5 GW.

Therefore, one of the **major levers for decarbonizing the economy, in addition to savings and efficiency, is electrification.** The electrification of the economy is increasing as one of the key vectors of decarbonization, rising to 35% in 2030, with new projects, greater electrification in industry and mobility, more green hydrogen production, and new demands associated with new services related to the digital transformation of our economy. Finally, green hydrogen is another key player in this update process, with high penetration of this vector expected in industry, one of the key sectors to be decarbonized.

Energy savings

The EU Energy Efficiency Directives stipulate that Member States must achieve cumulative final energy savings for the periods 2014-2020 and 2021-2030, with annual savings targets. For the second period, Directive 2023/1791 adjusts the savings targets to an average of 1.49% per year, with staggered targets ranging from 0.8% to 1.9%. The savings are the result of consumption that does not occur due to process substitution or changes in system conditions.

Spain will use the permitted flexibility mechanisms if it achieves the targets for the first years of the 2021-2030 period. In addition, 12.35% of the savings target must be allocated to reducing energy poverty, benefiting vulnerable households, according to Eurostat indicators on housing conditions, ability to pay for services, and risk of poverty.

Energy efficiency

Spain's national energy efficiency target for 2030 focuses on reducing energy consumption and promoting the use of renewable energies, in line with the European Union's strategy and initiatives such as "Target 55" and "REPowerEU." Energy efficiency is a priority under the "energy efficiency first" principle promoted by the European Commission and is considered crucial for decarbonization and economic sustainability. Efficiency means ensuring that the same process achieves its goals with less energy consumption.

This plan seeks to reduce energy consumption through various measures, especially in sectors such as transportation, industry, and buildings. In turn, it has environmental benefits, as it reduces the use of fossil fuels and the need for energy infrastructure. The EU Energy Efficiency Directive sets targets for improving efficiency by 40.5% in primary energy and 38% in final energy by 2030. Spain plans to exceed these targets, achieving a 43% improvement in final energy efficiency.

Electrification and deployment of renewables

The PNIEC is clear on this issue: 3 out of every 4 tons of GHG emissions originate in the energy system, so its decarbonization is key to achieving the Plan's objectives. To achieve this goal, it is necessary to reduce consumption (savings and efficiency) and transition from fossil fuels to renewable energies.

In addition, it is necessary to electrify a significant part of thermal and transport demand and to move towards an increasingly distributed and flexible system. Self-consumption also contributes significantly to this electrification of demand, increasing installation forecasts to 19 GW in 2030, which is expected to cover 11% of demand.

Achieving the ambitious targets set in this area therefore requires action focused on three strategic lines:

- Promotion of large-scale generation projects.
- Deployment of self-consumption and distributed generation.
- Measures to promote flexibility, including energy storage and demand management, which will favor greater integration of renewables into the system and the electricity market.

The large-scale development of renewable energies over the last decade at the international level has led to a substantial reduction in their relative costs. In international references, renewable sources (mainly wind and solar) generate the most economical electricity. The cost of hydroelectric generation depends on the amortization of investments.

In view of the planned deployment of renewable technologies in the electricity sector, measures such as the establishment of auction schedules, which regulate the entry of new renewables, bringing forward the savings they represent for consumers on their bills, administrative procedures that ensure compliance with environmental criteria, and the management of permits for access to the electricity grid that prioritize those projects with the greatest benefits, are relevant.

Generation fleet under the PNIEC 2023–2030 scenario. Gross capacity (MW)				
Years	**2019**	**2020**	**2025**	**2030**
Wind	25.583	26.754	36.149	62.054
Solar fotovoltaic	8.306	11.004	46.501	76.277
Solar thermal	2.300	2.300	2.304	4.804
Hydropower	14.006	14.011	14.261	14.511
Biogas	203	210	240	440
Other renewables	0	0	25	80
Biomass	413	609	1009	1409
Coal	10.159	10.159	0**	0
Combined cycle	26.612	26.612	26.612	26.612
Cogeneration	5.446	5.276	4.068	3.784
Fuel oil and fuel oil/gas (Non-pensinsular territories)	3.660	3.660	2.847	1.830
Waste and other fuels	600	609	470	342
Nuclear	7.399	7.399	7.399	3.181
Storage*	6.413	6.413	9.289	18.913
Total	**111.100**	**115.015**	**151.173**	**214.236**

** Including solar thermal storage, capacity reaches 22.5 GW.*

*** The phase-out of coal-fired generation will be subject to an assessment by the System Operator of compliance with system security of supply criteria, as established in Article 137 of Royal Decree 1955/2000.*

Source: Update of the PNIEC 2030 (MITERD, 2024)

3 Legal landscape

The legal landscape and regulations applicable to the energy transition in Spain have evolved in recent years in response to international environmental commitments, particularly the EU regulatory framework, technological advances, and social and institutional demands for sustainability and the fight against climate change.

In this context, in 2019 the Spanish government approved the Strategic Energy and Climate Framework, which contains various strategic and legislative elements aimed at setting out the main lines of action on the path to climate neutrality. Among the fundamental parts of this Framework, the first to be mentioned is the "*Long-Term Decarbonization Strategy*" (2020), which has been developed in accordance with the guidelines of Regulation *(EU) 2018/1999 of the European Parliament and of the Council of December 11, 2018, on the governance of the Energy Union and Climate Action*, which establishes the need for Member States to develop long-term strategies with a perspective of at least 30 years. Secondly, the publication of *Law 7/2021 of May 20 on Climate Change and Energy Transition*, which establishes the regulatory framework to ensure Spain's compliance with the objectives of the Paris Agreement, facilitate the decarbonization of the economy, and promote a sustainable development model.

Also, of a cross-cutting nature is the Just Transition Strategy, approved in 2019, whose main objective is to maximize employment opportunities and minimize the social and economic impacts of the energy transition.

The key aspects of the regulation in this area are detailed below, focusing on the following areas: energy efficiency and savings, electrification-storage, territorial planning for renewable energies, and the promotion of individual and collective self-consumption.

1. Energy Efficiency and Savings

Energy efficiency and savings are essential principles in the transition to a decarbonized energy model. Spanish regulations have established measures to reduce energy consumption in the building, industry, and transportation sectors. In this context, the following stand out:

- European Energy Efficiency Directive (EU) 2018/2002 of the European Parliament and of the Council of December 11, 2018, amending Directive 2012/27/EU: Spain has adopted this European regulation, which establishes a framework of measures to promote efficiency in all sectors. Through successive royal decrees, mandatory energy audits, energy management systems, and the creation of energy service companies (ESCOs) have been implemented.

- Integrated National Energy and Climate Plan (PNIEC 2021-2030): As mentioned above, this plan includes specific energy-saving and efficiency targets, such as reducing primary and final energy consumption. It also promotes the energy renovation of buildings, with subsidies and direct aid to boost efficiency improvements in the residential and public sectors.

Actions to improve the energy efficiency of buildings have been included in the *Long-Term Strategy for Energy Renovation in the Building Sector in Spain (ERESEE)*, which has different pieces of legislation. These include the Technical Building Code (CTE), the Regulation on Thermal Installations in Buildings (RITE), and the Energy Certification System for Buildings, among others. The CTE, updated in August 2025, imposes nearly zero energy consumption requirements on buildings, promoting savings, the use of renewable energies, and the reduction of emissions.

Measures to promote energy efficiency include a wide variety of legislative and/or financial support actions. The most important structural instrument of the previous period (2014-2020) in this regard was the establishment of the *National Energy Efficiency Obligations System (SNOEE)*, together with the creation of the *National Energy Efficiency Fund (FNEE)* to finance national energy efficiency initiatives (as provided for in Law 18/2014 of October 15, approving urgent measures for growth, competitiveness, and efficiency). By means of *Royal Decree-Law 23/2020, of June 23, approving measures in the field of energy and other areas for economic recovery,* the validity of the SNOEE is extended until December 31, 2030, in accordance with the provisions of *Directive 2018/2002*.

2. Electrification and energy storage

The electrification of transport and industry is a basic pillar of the energy transition in Spain. The regulations seek to replace the use of combustion engines and thermal uses of fossil fuels with electricity generated predominantly from renewable sources. Some key instruments include:

- Law 7/2021 on Climate Change and Energy Transition sets targets for decarbonizing the economy and establishes carbon neutrality by 2050, promoting the use of renewable electricity in all sectors.
- Within the PNIEC and the MOVES Plan, a significant portion of subsidies and grants are allocated to the implementation of electric mobility by supporting the purchase of electric vehicles and promoting charging infrastructure throughout the country.
- Electrification in Industry: The Long-Term Decarbonization Strategy (EDLP) highlights efforts towards greater electrification of the industrial sector by switching machinery and processes to the use of electricity instead of fossil fuels.

For energy storage, Royal Decree 1183/2020, which enables the possibility of hybridizing facilities; Royal Decree-Law 6/2022, which facilitates its processing; and Royal Decree-Law 8/2023, which recognizes hydraulic energy storage as an element that contributes to decarbonization by helping to secure the electricity system by integrating other non-manageable renewable energies and reducing waste.

3. Territorial Planning for Renewable Energies

Alongside the general objectives set out in the PNIEC, it should be borne in mind that the expansion of renewable energies requires careful territorial planning to minimize their environmental, economic, and social impact and achieve their best territorial integration. In Spain, this competence lies with the autonomous communities, which is why the main regulatory instruments in this area are land use plans (POT). These instruments, which fall within the competence of the autonomous communities, make it possible to regulate the installation of wind and photovoltaic farms, considering environmental and territorial constraints, as well as their compatibility with other economic activities. These instruments have not been satisfactorily developed due, on the one hand, to the fact that most of them were approved prior to the boom in the implementation of renewable energy facilities and, on the other hand, to the compromised definition of regulatory criteria for considering territories suitable.

4. Promotion of Self-Consumption

The main regulations and measures in this area are:

- The Energy Efficiency Directive (2023/1791) establishes minimum standards for self-consumption and renewable energy communities throughout the EU. In addition, NextGen funds can be used for self-consumption projects.
- Royal Decree 244/2019: Regulates the administrative, technical, and economic conditions for electricity self-consumption in Spain, eliminating barriers such as the "sun tax" and allowing compensation for surplus energy produced.
- Tax Incentives and Subsidies: Through the PNIEC and other policies, various financial subsidies and tax deductions have been made available for self-consumption installations, such as solar roofs on buildings and neighborhood communities.
- Shared Self-Consumption: The regulatory framework now allows shared self-consumption in residential buildings and between companies in industrial parks, promoting the democratization of renewable energy production and consumption on a smaller scale through **energy communities.**

The implementation of self-consumption measures has led to exponential growth in this supply solution since 2019, following the approval of Royal Decree 244/2019, the launch of the Self-Consumption Roadmap, and, fundamentally, the aid provided for in Royal Decree 477/2021 of June 29 on incentive programs linked to self-consumption and storage with renewable energy sources, as well as the implementation of renewable thermal systems in the residential sector, within the framework of the Recovery, Transformation, and Resilience Plan.

5. Conclusions

The energy transition in Spain is based on regulations largely derived from European standards that seek to accelerate decarbonization and promote sustainability in all sectors.

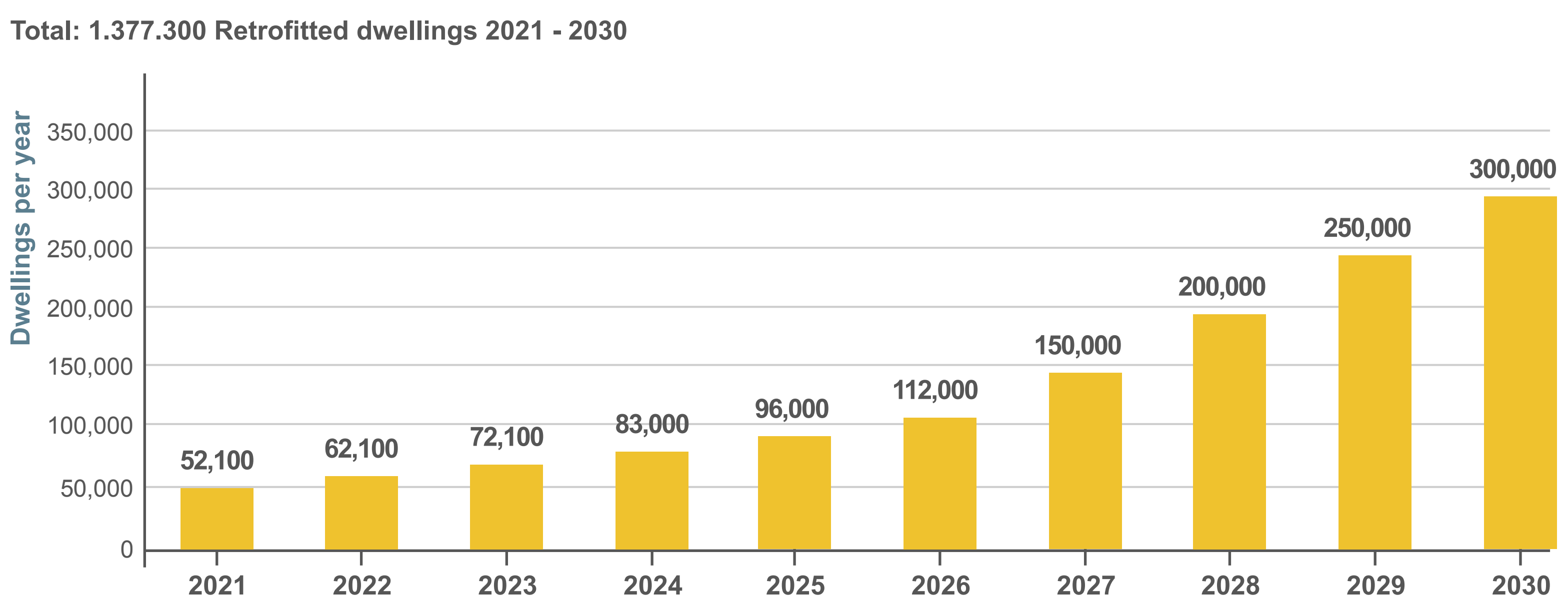
The policy is based on four key aspects (efficiency and savings, electrification-storage, renewable energy planning, and promotion of self-consumption) that form the basis of the current regulatory landscape, reflecting Spain's commitment to combating climate change and building a more resilient, fair, and environmentally friendly energy model that respects the most vulnerable groups in this transition. The challenge towards 2030 and 2050 involves not only meeting the established targets but also continuously adapting regulations to respond to emerging challenges in this transition process.

4 Saving measures

1. Building (energy renovation of buildings)

La construcción convencional del parque de viviendas y edificios está dando paso a soluciones más sostenibles que permiten reducir los consumos de energía, principalmente electricidad y térmica. El PNIEC (actualización de 2024) prevé incrementar el número de viviendas rehabilitadas energéticamente hasta 1.377.000, al aplicar la palanca de las inversiones del PRTR y un nuevo marco normativo en torno a la Directiva de Eficiencia Energética en Edificios. Este Plan prioriza las inversiones sobre la envolvente térmica (fachadas, cubiertas y cerramientos). Según se observa en el gráfico adjunto, para cumplir este objetivo es preciso acometer sin tardanza un esfuerzo de gran envergadura.

Indicative annual forecast of energy-renovated homes 2021-2030



Source: Ministry for the Ecological Transition and the Demographic Challenge, 2023

Among the measures planned for the energy renovation of residential buildings is Measure 2.8, which focuses on the residential sector with a savings target of 4,979 ktep of final energy accumulated during the period 2021–2030. Specific actions that enable savings to be achieved include insulation (the main one), adjusting air conditioning temperatures to values that are not too extreme, turning off and unplugging electronic devices when not in use, reducing the maximum hot water temperature, turning off unnecessary lights, and closing windows and doors when air conditioning devices are on, etc.

2. Industry (with little room for improvement)

Energy savings consist of reducing consumption by changing behavior, which affects production and services. In the field of savings, the industrial sector has little room for improvement in production processes; however, the savings measures mentioned for the residential building sector can be applied to industrial facilities.

3. Mobility (reduction of mechanized travel)

Mobility savings measures should be aimed at reducing motorized travel and promoting the use of non-energy-consuming modes of transport, such as walking and cycling. This measure requires urban design that is in line with sustainable mobility parameters that minimize the use of private vehicles, thereby contributing to the reduction of final energy consumption and CO_2 emissions, as well as improving air quality. This issue is an essential part of national instruments and plans, some of which are detailed below.

The PNIEC 2021-2030, following its update in 2024, sets a cumulative energy saving target of 53,593 ktep for the period 2021-2030. In this regard, the transport sector is expected to contribute most to the achievement of this savings target, with an allocation of 19,938.9 ktep, representing 37% of the cumulative energy savings target for the period mentioned.

The PNIEC proposes five measures related to transport and mobility, one of which is aimed at energy savings in this sector:

- Measure 2.1. Low-emission zones and sustainable urban mobility.
  - Savings target: 6,604.7 ktep of cumulative final energy during the period 2021–2030.

Within the framework of the 2030 Safe, Sustainable, and Connected Mobility Plan and Law 7/2021 of May 20 on Climate Change and Energy Transition, commuting plans or mobility plans are being developed to promote a series of measures to reduce energy consumption in commuting by encouraging teleworking and flexible working hours, to reduce weekly commutes, and to encourage employees to cycle or walk to work every day.

On the other hand, the Sustainable Mobility Law, whose draft bill was approved in February 2024 but whose passage through Congress is still uncertain, establishes four fundamental pillars to ensure that the population can enjoy sustainable mobility that contributes to achieving greenhouse gas reduction targets and improving air quality. One of these pillars focuses on achieving clean and healthy mobility, prioritizing the creation of measures that promote and encourage more sustainable and healthy modes of mobility in urban and metropolitan environments, with an emphasis on active mobility (walking or cycling).

Spain has several plans, strategies, and initiatives that seek to promote energy savings in freight transport, advocating for the criterion of proximity in logistics. In this regard, the Spanish Circular Economy Strategy 2030 advocates for a reduction in product transport distances by optimizing routes and decentralizing logistics centers, promoting proximity in production and distribution. Other instruments, such as the Recovery, Transformation, and Resilience Plan and the Spanish Urban Agenda, opt for the creation and management of local logistics centers to promote local logistics that reduce long-distance transport, with the consequent energy savings in the sector.

5 Efficiency measures

1. Building (aerothermal energy)

According to the Long-Term Strategy for Energy Renovation in the Building Sector in Spain (ERESEE, 2020), Spain's residential housing stock has a wide range of problems, which can be summarized in three areas: conservation, universal accessibility, and energy efficiency, the latter being one of the most significant shortcomings in terms of the challenges and demands of today's society.

Based on estimates made by ERESEE (2020) and PNIEC 2021-2030 (before its 2024 update), the aim is to move from the current level of 25,000 homes refurbished per year to the PNIEC target of 300,000 by 2030. From this point onwards, the figures are expected to stabilize at around 350,000 homes/year undergoing deep renovation (including the building envelope) during the decade 2030-2040, before gradually falling to 150,000 homes/year in 2050. This means that the total number of homes deeply renovated between 2020 and 2030 would be 1,200,000 (1,377,000 homes after the PNIEC update in 2024) and another 5,900,000 between 2031 and 2050, for a total of 7,100,000.

The European Union, through Directive (EU) 2024/1275—on the energy performance of buildings—establishes the need to improve sustainability and energy efficiency in the heating and air conditioning systems of buildings. It also establishes the complete elimination of fossil fuel boilers by 2040 and the goal of achieving a climate-neutral housing stock by 2050.

In this regard, aerothermal energy, an air conditioning and domestic hot water production system based on the use of heat pumps to extract heat from the outside air, is one of the best technological alternatives for achieving this goal. Replacing conventional heating and air conditioning systems with aerothermal energy will improve energy efficiency, reducing the negative effects on the environment resulting from the use of fossil fuels and promoting self-consumption with renewables or the use of predominantly renewable electricity generation.

The latest reform of the Regulation on Thermal Installations in Buildings (RITE) (RD 178/2021) establishes that part of the energy needs of buildings must be covered by the incorporation of renewable or residual heat utilization systems. To achieve this objective, the combination of electricity self-consumption based on small photovoltaic installations in buildings and aerothermal systems (powered by this renewable energy source) is the best option. This scheme will imporve energy efficiency in buildings, with the consequent reduction in fossil fuel consumption and mitigation of greenhouse gas emissions.

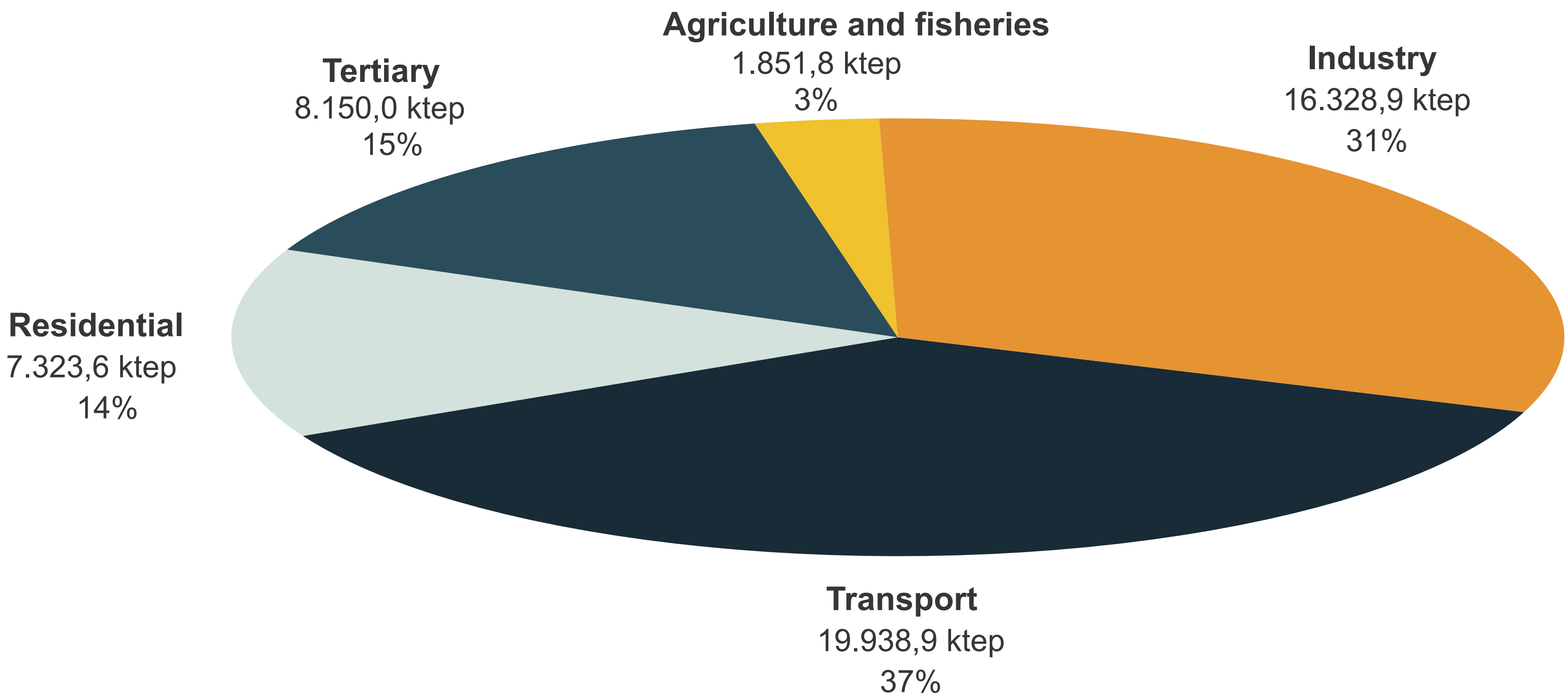
The PNIEC proposes three measures related to the energy renovation of residential buildings, in addition to a package of measures associated with energy efficiency for other types of buildings:

- Measure 2.8. Energy efficiency in existing buildings in the residential sector.
  - Savings target: 4,979 ktep of final energy accumulated during the period 2021–2030.
- Measure 2.9. Renovation of residential equipment.
  - Savings target: 1,745 ktep of final energy accumulated during the period 2021–2030.
- Measure 2.10. District heating and cooling networks in the residential sector.
  - Savings target: 599.0 ktep of final energy accumulated during the period 2021–2030.

2. Industry

The revised PNIEC anticipates that the transport and industrial sectors will contribute most to the cumulative final energy savings target for the period 2021–2030, assigning them a combined savings target of 36,267.8 ktep, representing 68% of the cumulative energy savings target for the period.

Cumulative final energy savings by sector in Spain 2021-2030 (ktoe)



Source: Integrated National Energy and Climate Plan 2023-2030

To achieve these targets, the PNIEC proposes two energy efficiency measures aimed at the industrial sector as part of a package comprising a total of 15 measures. Both measures will promote, on the one hand, a greater volume of investment in the renovation and upgrading or replacement of industrial equipment and facilities with poor energy performance with others that use high energy efficiency technologies or directly incorporate the best available techniques (BAT). It will cover the renovation or replacement of all types of energy-consuming systems in industrial processes or those that produce and/or transport steam or other heat transfer fluids.

- Measure 2.6. Improvements in technology and process management systems in non-energy-intensive industries.
  - Savings target: 9,283.5 ktep of cumulative final energy savings during the period 2021–2030.
- Measure 2.7. Improvements in technology and process management systems in energy-intensive industries.
  - Savings target: 7,045.4 ktep of cumulative final energy savings during the period 2021–2030.

The industrial sectors with the highest energy consumption in absolute terms in Spain (INE, 2022) are metallurgy, the manufacture of iron, steel, and ferroalloy products (1,779 ktep); the food industry (1,611 ktep); the chemical industry (1,533 ktep); and the non-metallic mineral products sector, including the ceramics industry (1,416 ktep). Some of the actions planned for implementation in these industrial sectors are listed below:

- Investment in modern technology: Adopting more energy-efficient technologies for key processes (high-efficiency furnaces, heat recovery systems, automation and process control, high-efficiency electrolysis, material pre-treatment technologies, high-efficiency motors and equipment, filtration and emission reduction technology, etc.).
- Energy audits: Their mission is to identify areas of high energy consumption and find opportunities for improvement.
- Energy management systems: Implement systems to monitor, control, and optimize energy use.
- Renewable energies: Incorporating renewable energy sources to reduce dependence on conventional energy sources.

3. Mobility (rail and urban and interurban public transport)

Currently, in Spain, the use of private vehicles for daily commutes is much higher than the use of public transport. In relation to commuting, the INE (Spanish National Statistics Institute) states that around 60% of people use private vehicles compared to 12% who use public transport. In this regard, measures to achieve sustainable and efficient mobility should focus on promoting both urban and interurban public transport through the management and planning of these services, among other aspects.

The three measures proposed by the PNIEC associated with energy efficiency in mobility are:

- Measure 2.2. Modal shift in freight transport with greater use of rail.
  - Savings target: 4,403.1 ktep of cumulative final energy savings during the period 2021–2030.
- Measure 2.3. Replacement of rolling stock with more efficient means of transport and efficiency improvements in management.
  - Savings target: 3,105.0 ktep of cumulative final energy savings during the period 2021–2030.
- Measure 2.4. Improving the efficiency and sustainability of ports
  - Savings target: 1,984.9 ktep of cumulative final energy savings during the period 2021–2030.

The energy-saving measures in the field of mobility included in the PNIEC forecast a saving of 19,938.9 ktep. It not only involves saving energy or reducing fossil fuel consumption but also prioritizing increasing energy efficiency by promoting **modal shifts in transport, committing to an increase in the use of public transport**—currently accounting for 2% of final energy consumption compared to 83% for road transport, according to IDAE—**or the use of shared vehicles** (carpooling and carsharing).

To improve energy efficiency in freight transport in Spain, the PNIEC proposes—among other measures—a modal shift that increases the share of rail freight. This approach is based on the fact that rail is one of the most energy-efficient modes of transport in terms of energy consumption per ton-kilometer, as it reduces fuel use and emissions when moving large volumes of goods compared with road transport.

Currently, rail freight accounts for only 4.8% of total tonne-kilometers transported. For this reason, the 2030 Strategy for Safe, Sustainable, and Connected Mobility sets out, under Axis 6.1, a targeted increase in rail freight with the aim of raising its modal share to 10% by 2030.

Increasing the **transport of goods by sea through coastal shipping** would also improve energy efficiency in this sector. The increase in this type of transport compared to road freight transport can be accompanied by improvements in port logistics facilities and management to reduce the final energy consumption of a means of transport that allows for the loading of a greater quantity of goods than land transport.

Finally, the transition toward more efficient transport models—for both people and goods—also encourages the use of biofuels and renewable gases, such as green hydrogen. These technologies enable the production of alternatives for public and freight transport, as well as technological improvements in the manufacture of vehicles that reduce their energy consumption and enable more sustainable mobility by reducing fossil fuel consumption.

6 Electrification

1. Building

Improving electrification levels in the residential sector focuses on replacing fossil fuel-based heating and cooling boilers, both petroleum and gas-based. In addition, greater use of electricity in buildings can be achieved by replacing gas for DHW and cooking with electrical solutions.

2. Industry

Along with mobility, industry is one of the sectors with the greatest potential for electrification and reduction in the use of fossil fuels. The progressive electrification of Spanish industry would have very favorable repercussions on the economic, environmental, and social aspects of the sector.

From an economic perspective, electrification can significantly reduce operating costs and increase energy efficiency, as electrical equipment is generally more efficient and less expensive to maintain than fossil fuel-powered equipment. In addition, electricity prices are less volatile than fossil fuel prices, which facilitates better financial predictability.
In environmental terms, electrification is a crucial strategy for reducing greenhouse gas emissions. This is particularly relevant for industries that have traditionally been large emitters of CO_2, such as metallurgy and chemicals.

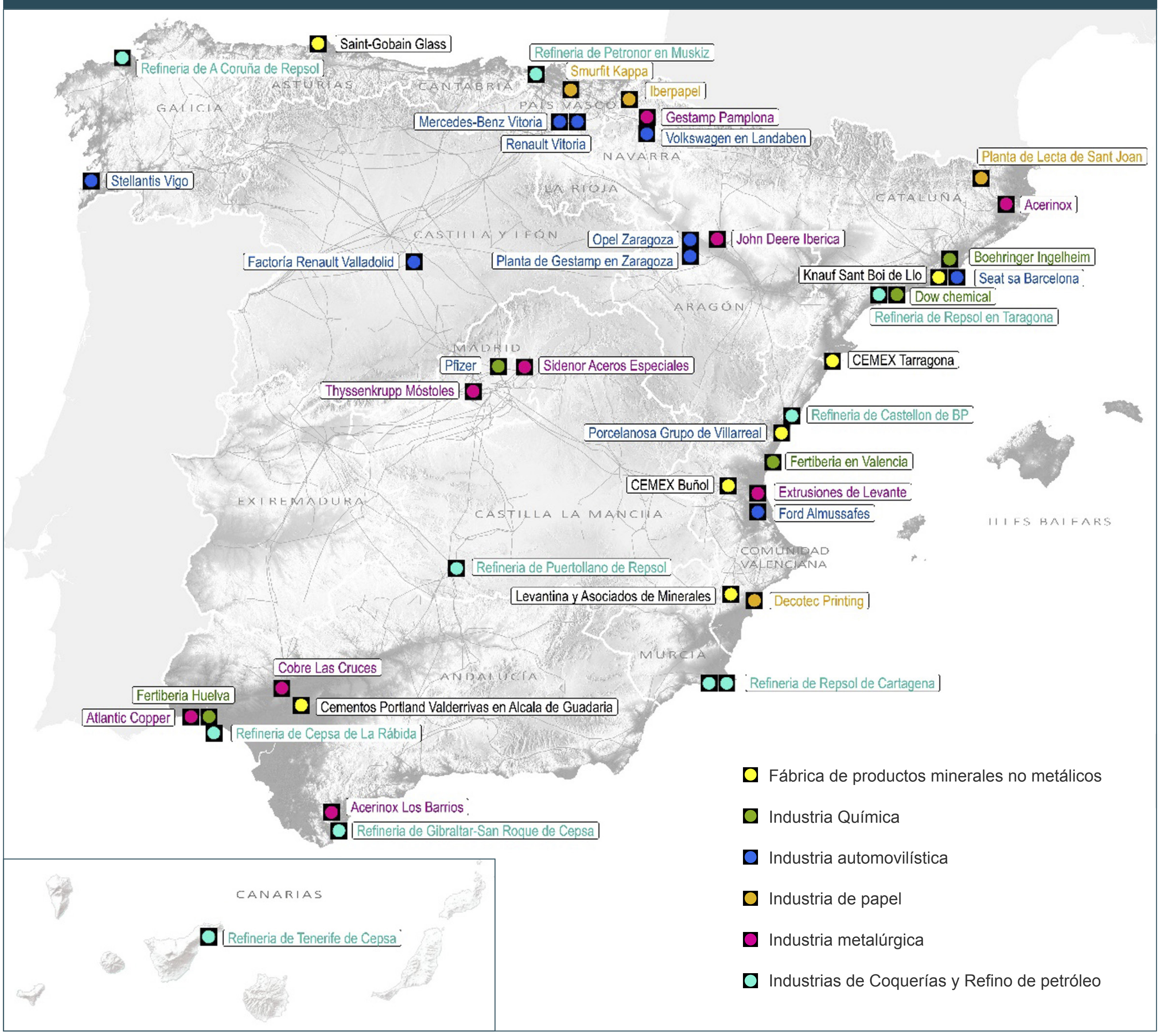
In the social sphere, electrification can create green jobs and improve public health by reducing pollutant emissions. The creation of new jobs in sectors related to renewable energy and energy efficiency is an additional advantage that contributes to sustainable economic development.

In short, the electrification of industries is not only a step towards environmental sustainability, but also a viable strategy for improving operational efficiency and economic competitiveness.

In Spain, energy-intensive industries are mainly concentrated in areas with a strong industrial tradition (Catalonia and the Basque Country) and access to adequate infrastructure (Valencia and Andalusia). The most prominent regions are listed below, along with their industrial specialization:

- Basque Country, with a strong specialization in steelmaking and metallurgy, although the paper industry also stands out.
  - Key geographical areas: Bilbao, Barakaldo, Sestao
- Catalonia, whose specialization is focused on the chemical, petrochemical, and food industries.
  - Key geographical areas: Tarragona (petrochemical hub) and Barcelona.
- The Valencian Community, which stands out for its concentration of ceramics, chemical, and paper industries.
  - Key geographical areas: Castellón (ceramics), Valencia (chemicals and paper).
- Andalusia, with its two petrochemical industrial hubs in Huelva and Algeciras Bay, as well as its metallurgical and cement industries.
  - Key geographical areas: Huelva and Algeciras (oil refining), Seville (metallurgy), Malaga (cement).

ENERGY-INTENSIVE INDUSTRY



Source: Own elaboration, 2024

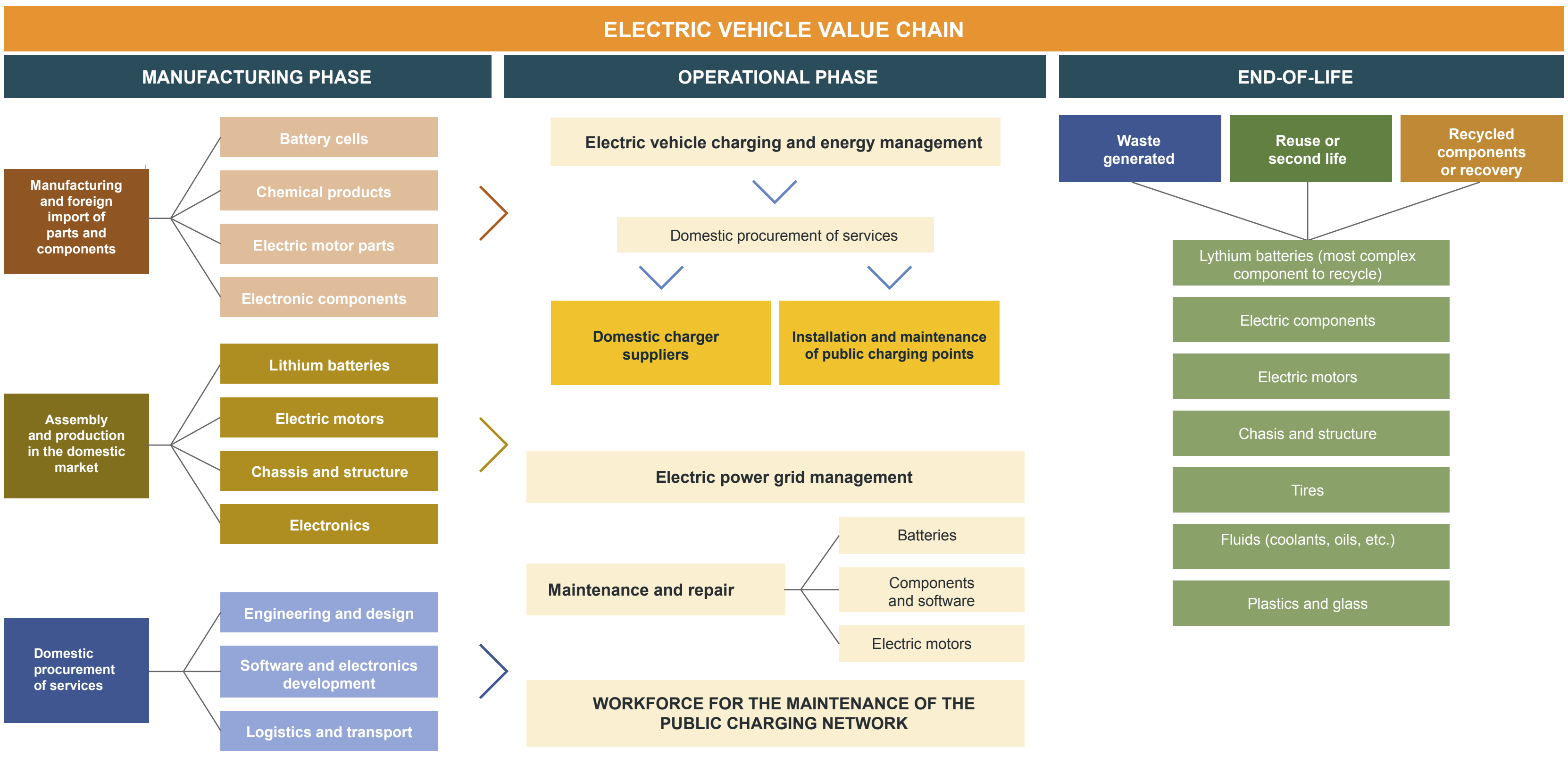
However, the electrification of industry is very difficult with current technologies, given that some sectors require very high-temperature thermal energy, such as the metal, ceramics, glass, cement, and chemical industries. In line with the respective roadmaps, renewable hydrogen, biogas, and biomethane are currently the priority energy vectors for addressing this challenge.

3. Mobility. Electric vehicle value chain

The last measure that the PNIEC dedicates to mobility corresponds to the promotion of electric vehicles (measure 2.5), which is estimated to provide savings in the period 2021-2030 of 3,841.20 ktep, reaching a fleet of 5,450,000 electric vehicles in 2030 (cars, vans, buses, and motorcycles). At the end of 2024, this fleet will not reach 600,000 units.

The arrival of hybrid and electric vehicles on the Spanish market around 2010 generated a series of changes in the automotive sector's value chain, directly affecting manufacturing and production processes, as well as the sale and circulation of this type of vehicle. As a result, the manufacture of electric vehicles currently depends on imports (from Asian countries such as China and Taiwan) of the main car components, which are then assembled in Spain.

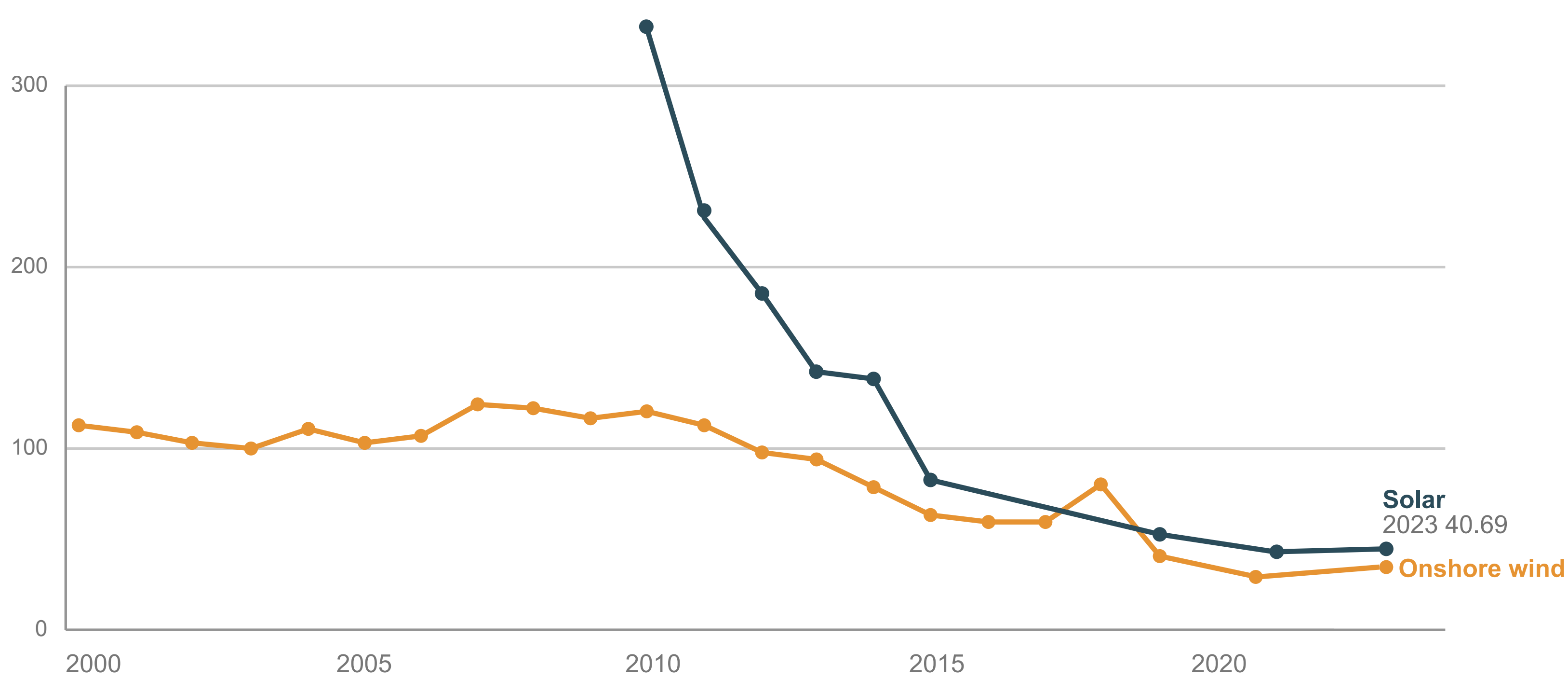
These changes in the production and manufacturing process are leading to alterations in national industries at different levels. Traditional manufacturing and production plants may see their size reduced due to the change in functionality (moving from manufacturing to the assembly of imported parts) and their designs redistributed (given the impossibility of assembling the new components in the old assembly location). In addition, it will lead to changes in the workforce, given the need to train staff in new aspects of the assembly line and to invest in engineering to adapt to technological developments.



Source: Own elaboration, 2024

7 Deployment of renewable energies

The cost (LCOE) of basic renewable energies has fallen dramatically in recent years. According to IRENA, the average cost in 2020 was €40.69/MWh for solar photovoltaic and €33.29/MWh for onshore wind.

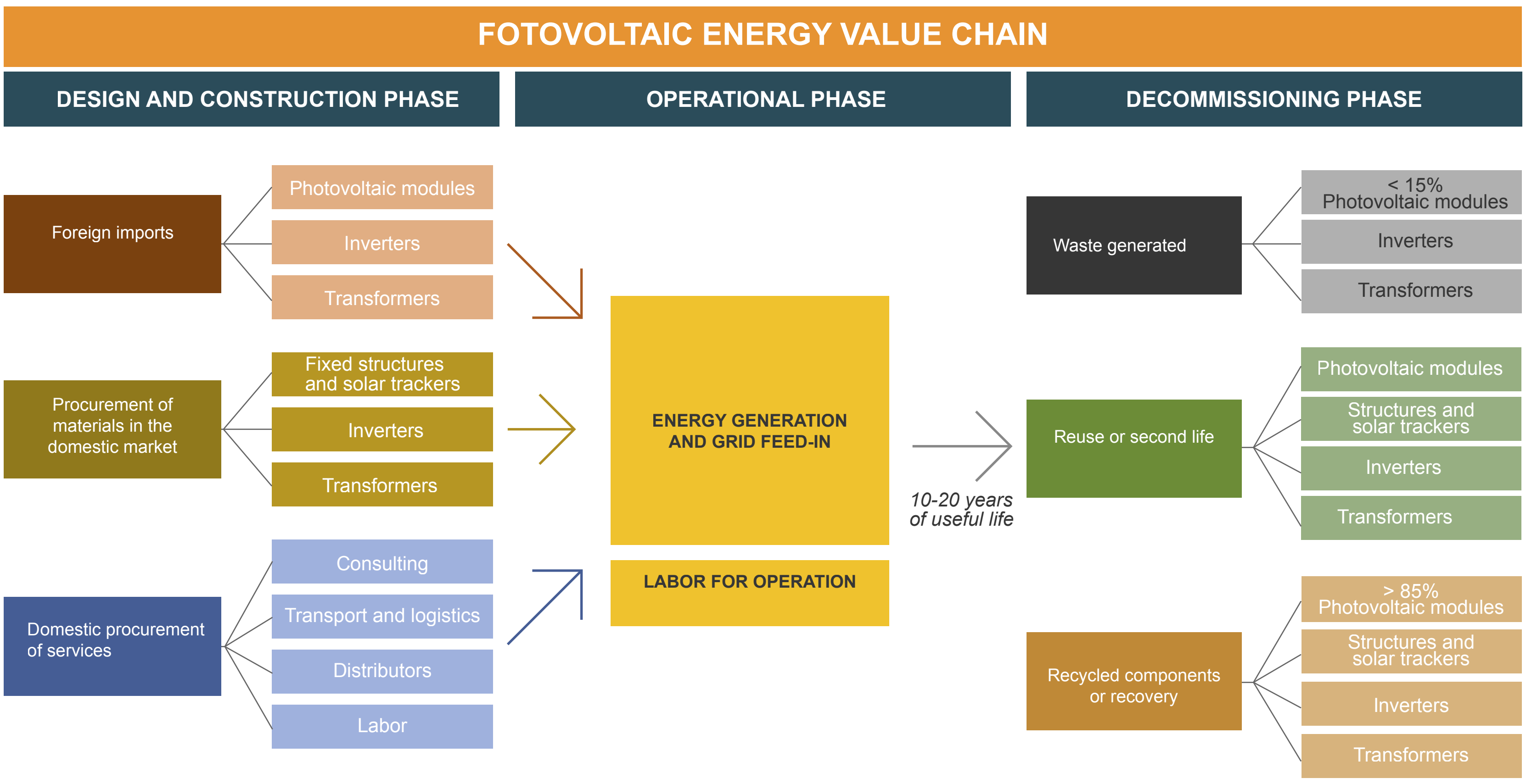


Fuente: IRENA Renewable Power Generation Costs in 2023 · Offshore wind not included due to limited data availability.

The cost of wind and solar generation. Source: IRENA Renewable Power Generation Costs in 2023

1. Photovoltaics. Value chain

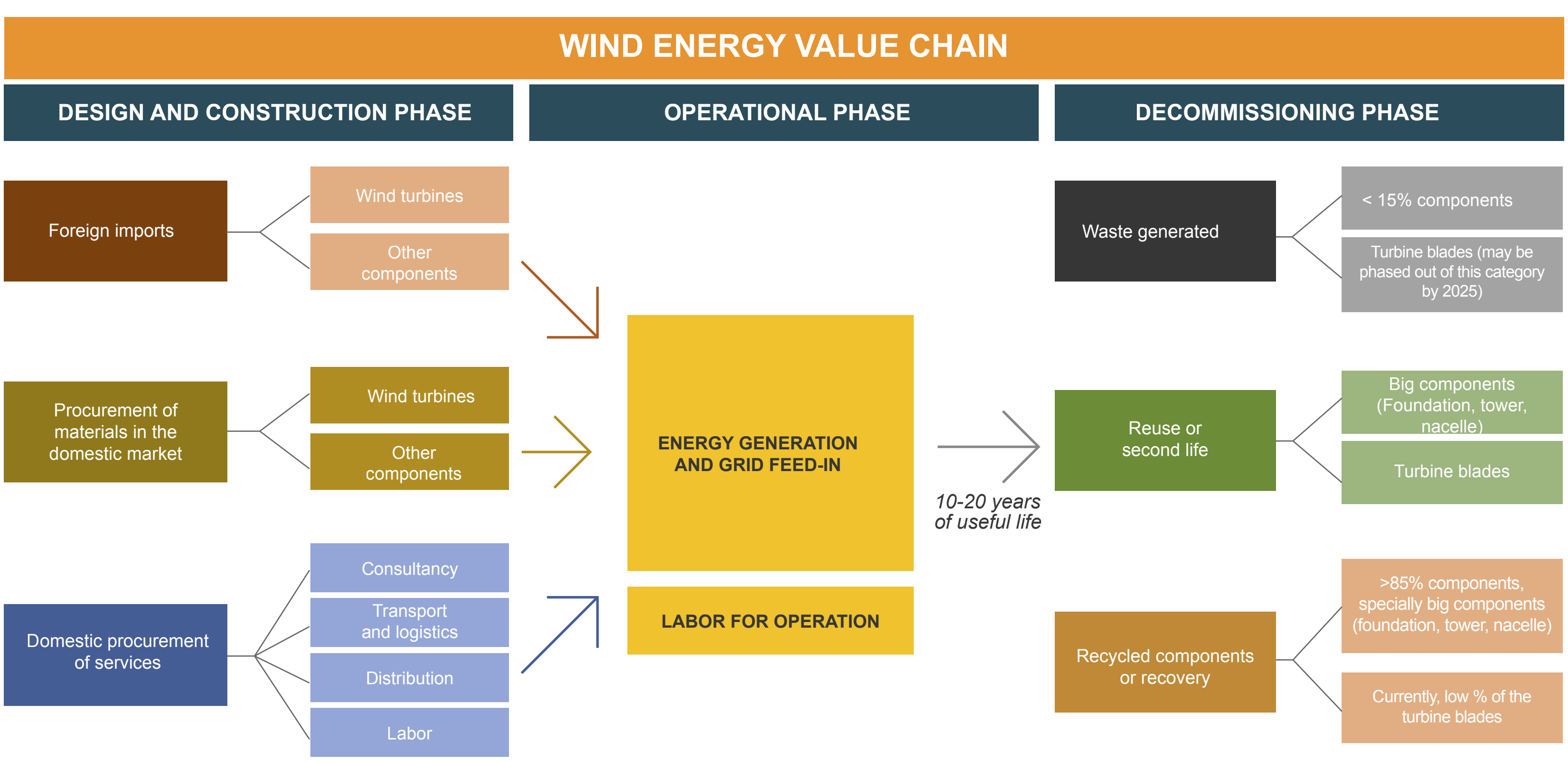
Spain has consolidated its leading position as a producer of the elements necessary for photovoltaic production, especially in high-value components such as solar trackers, structures, power electronics, and design. In addition, Spanish companies are among the world leaders, and the country can finance up to 65% of the costs of the components of a photovoltaic plant using national technology (UNEF, 2024). However, although there are domestic companies that manufacture components for photovoltaic installations, the remaining 35% of the costs (UNEF, 2024), corresponding to photovoltaic panels, are mainly produced in Asia.



Source: Own elaboration, 2024

2. Wind power. Value chain

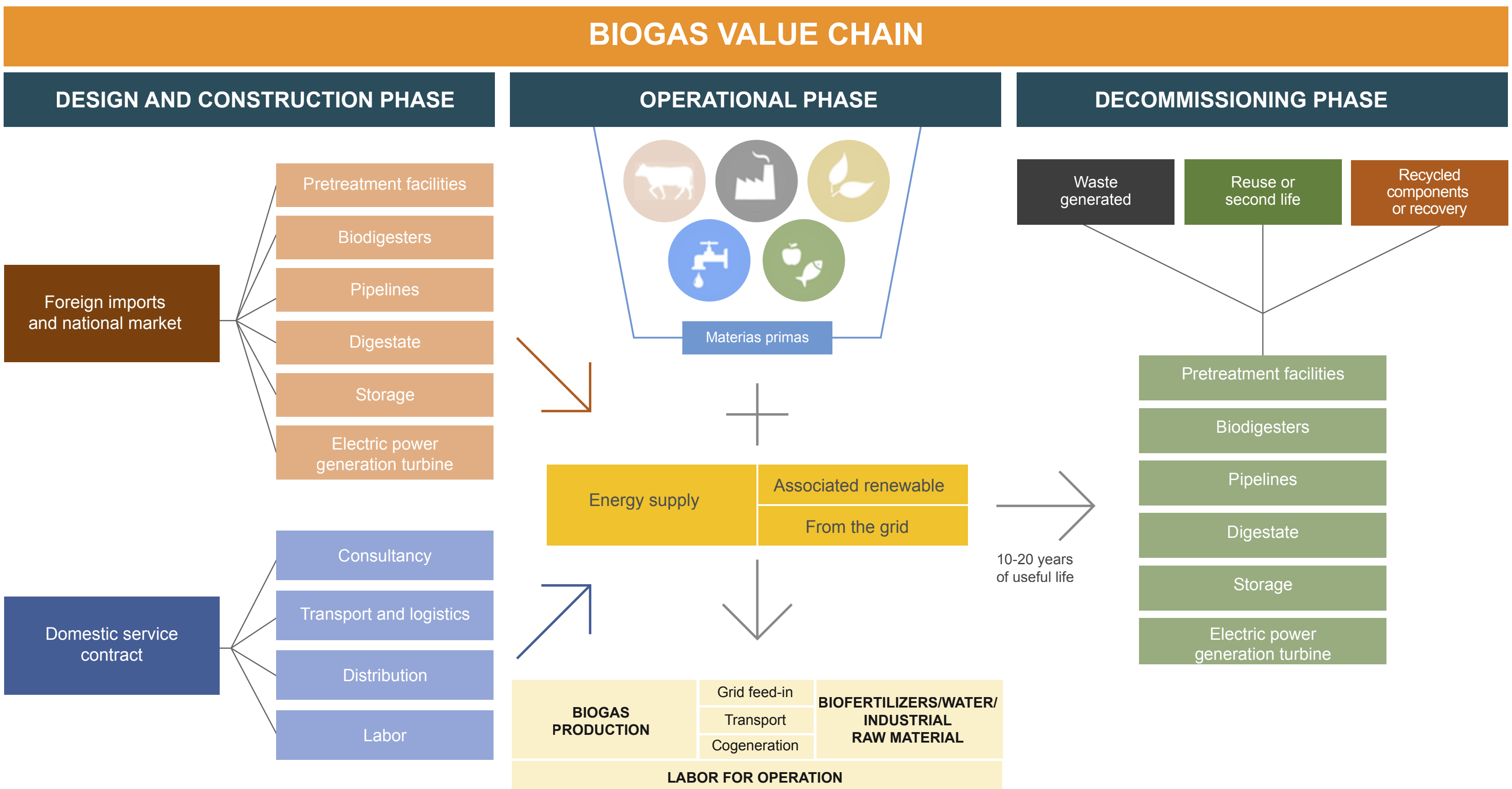
Wind energy is one of the key elements in the European Union and Spanish strategy to achieve a more sustainable energy system. According to the Spanish Wind Industry Catalog (AEE, 2024), this sector generates 40,000 highly skilled jobs, with exports exceeding €2.5 billion annually, placing us fifth worldwide. Wind energy has now become the main source of electricity generation in Spain (24% of the total). This remarkable advance in the penetration of wind energy has fostered the growth of various business activities, consolidating the Spanish sector as one of the global leaders in this field. In addition, the country remains a leader in the development of patents, ranking sixth globally.



Source: Own elaboration, 2024

9. Biogas. Value chain

According to the Biogas Roadmap (MITERD, 2022), there are 146 biogas facilities in Spain, of which 130 reported biogas consumption in 2020. The estimated biogas production at these plants in 2020 is around 2.74 TWh. Of this total, 2.45 TWh is consumed in power plants (cogeneration and non-cogeneration), of which 0.16 TWh is heat, with the rest (2.29 TWh) being electricity generation.

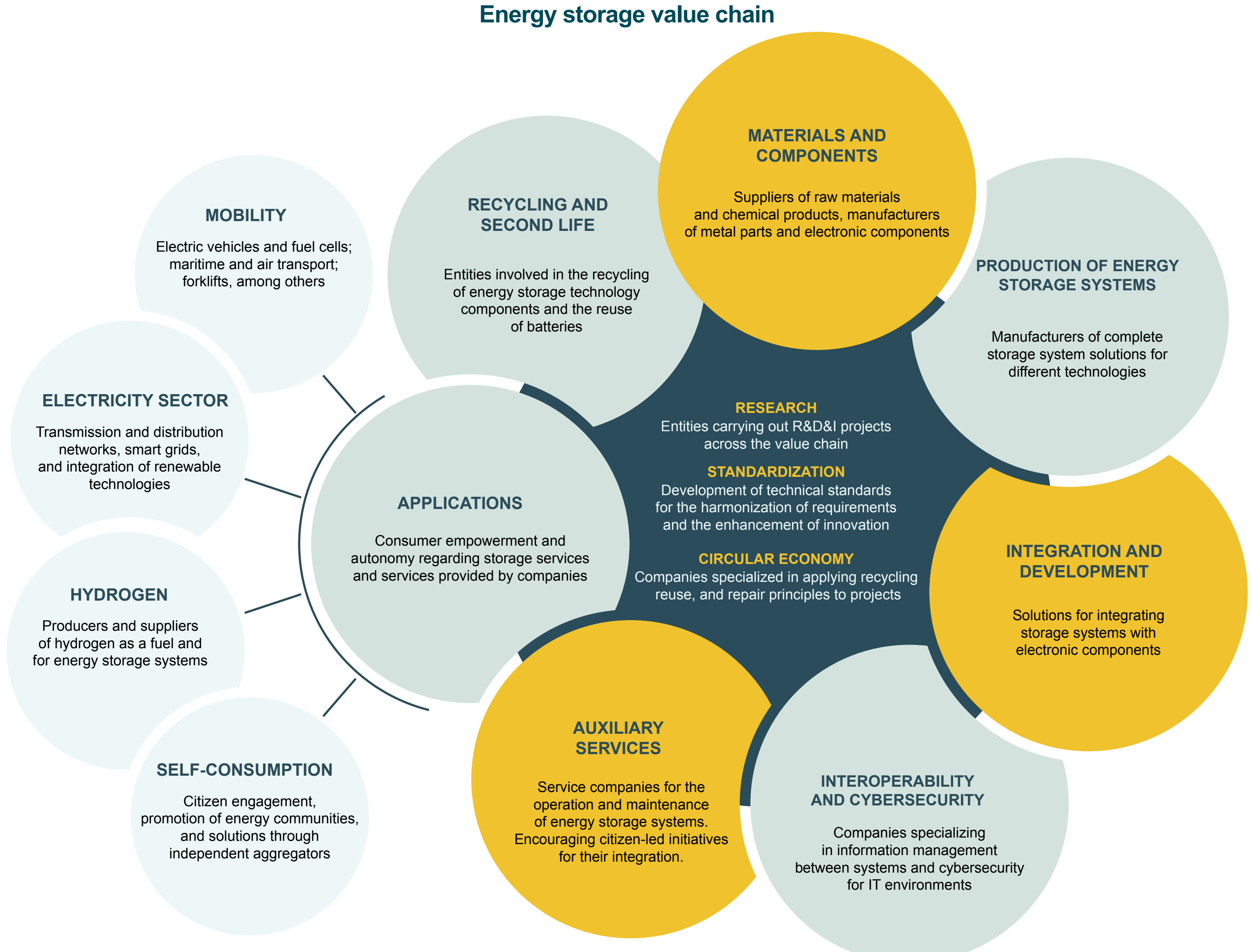


Source: Own elaboration, 2024

4. Storage. Value chain

Energy storage is the most nascent and necessary sector for the future, and currently the best-known technologies in Spain focus on hydroelectric pumping and batteries, in addition to other technologies (compressed air, thermal storage, supercapacitors, flywheels, and hydrogen fuel cells).

Energy storage value chain



Source: Energy Storage Strategy. Ministry for Ecological Transition and Demographic Challenge, 2021

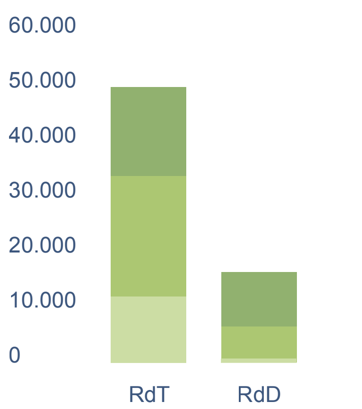
In the case of pumped storage hydroelectric power plants, in October 2024 there were 21 facilities in operation with a combined capacity of 5,380 MW throughout Spain, divided between some 3,300 MW of pure pumping plants (in which it is always necessary to pump water to the upper reservoir) and some 2,000 MW of mixed pumping (which can operate both as a conventional hydroelectric plant and as a reversible plant). In addition, some 20 facilities are in the planning stage, some of which already have permission to connect to the high-voltage grid (2,747 MW of power) and others for which authorization to connect to the grid has been requested (1,050 MW of power). The actions of Red Eléctrica de España itself in Gran Canaria are noteworthy, where it has promoted the Salto de Chira reversible pumped storage hydroelectric power plant, currently under construction, with a capacity of 200 MW. These large-scale energy projects, such as the hydroelectric power plant itself, are necessary to accelerate the energy transition and reduce external energy dependence. However, they generally tend to meet with strong social resistance.

For its part, **battery energy storage** technology is currently underdeveloped in Spain, given that in October 2024 only 16 MW are connected to the transmission grid and 11 MW to the distribution grid. However, 12. GW have been granted access and connection permits, and 8.9 GW are planned to be connected to the transmission and distribution grids.

RED ELÉCTRICA

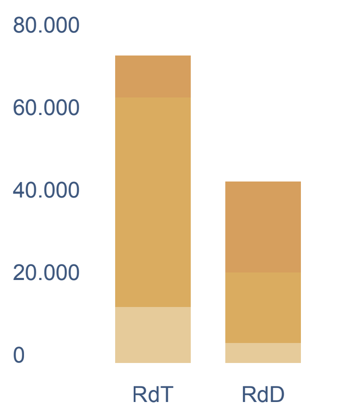
Access capacity data for installations (MW)

Wind



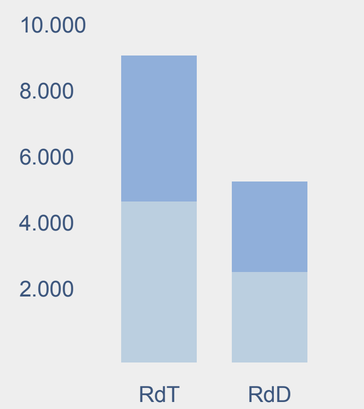
	RdT	RdD
Commissioned	15.795	9.074
Permitted	23.989	4.566
Under construction	10.396	1.152
Total	50.180	14.792

Fotovoltaic



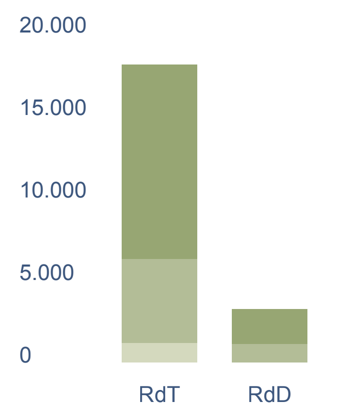
	RdT	RdD
Puesta en servicio	11.250	9.044
Con permisos	55.758	16.508
En curso	10.836	5.923
total	77.844	31.463

Batteries



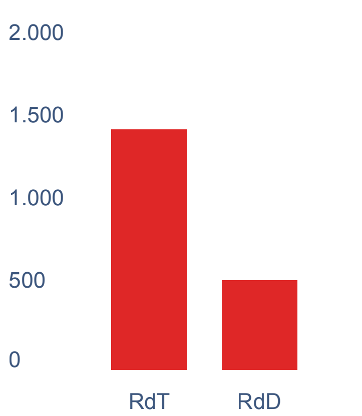
	RdT	
Puesta en servicio	37	11
Con permisos	2.368	6.797
En curso	4.752	3.148
total	7.157	9.876

Hybridization



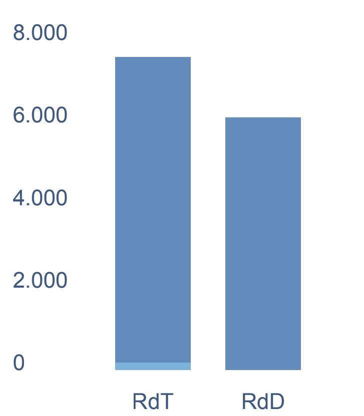
	RdT	RdD
Puesta en servicio	11.797	1.208
Con permisos	4.317	1.187
En curso	1.431	180
total	17.545	2.575

Termosolar



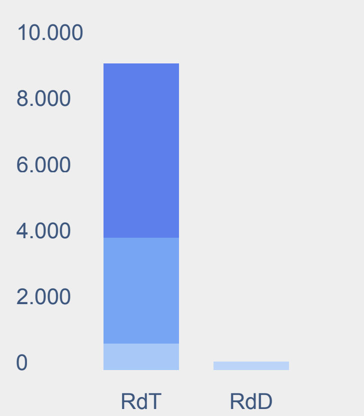
	RdT	RdD
Puesta en servicio	1.397	521
Con permisos	0	50
En curso	22	0
total	1.419	571

Hydropower



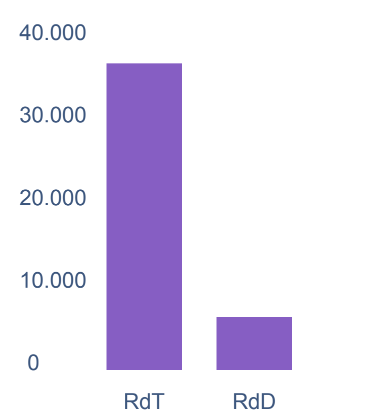
	RdT	RdD
Puesta en servicio	7.252	6.018
Con permisos	166	48
En curso	0	0
total	7.418	6.066

Pumped storage



	RdT	RdD
Puesta en servicio	5.347	0
Con permisos	2.747	0
En curso	896	154
total	8.990	154

Other technologies

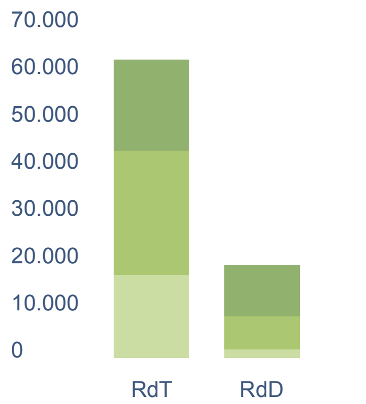


	RdT	RdD
Puesta en servicio	33.801	6.333
Con permisos	114	442
En curso	148	29
total	34.063	6.804

Source: Red Eléctrica de España, October 2024

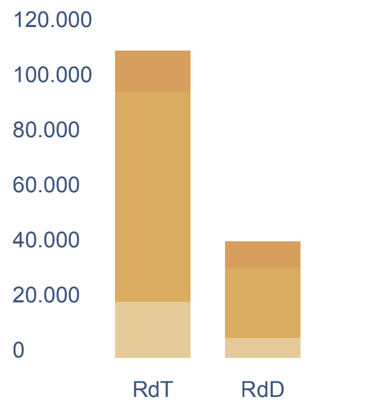
Installed capacity data for modules

Wind



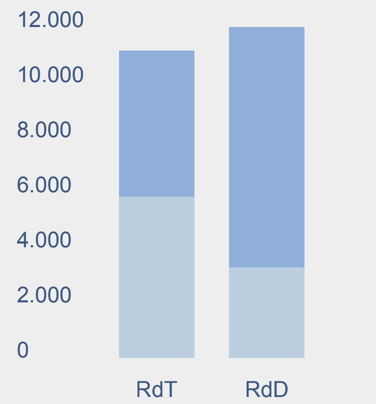
	RdT	RdD
Commissioned	21.010	9.804
Permitted	29.012	5.672
Under construction	12.782	1.235
Total	62.804	16.711

Fotovoltaic



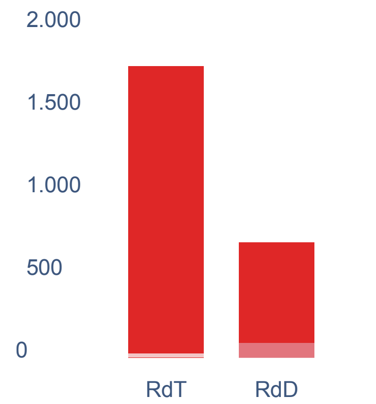
	RdT	RdD
Puesta en servicio	15.086	9.360
Con permisos	76.272	20.879
En curso	18.297	6.561
total	109.655	36.800

Batteries



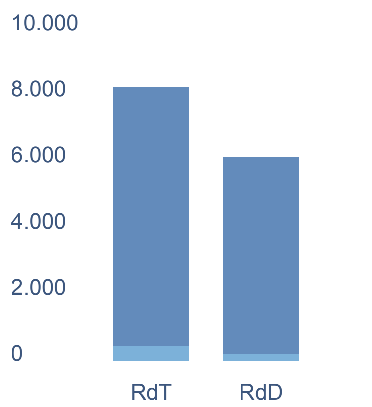
	RdT	RdD
Puesta en servicio	16	11
Con permisos	4.485	7.494
En curso	5.551	3.396
total	10.052	10.901

Termosolar



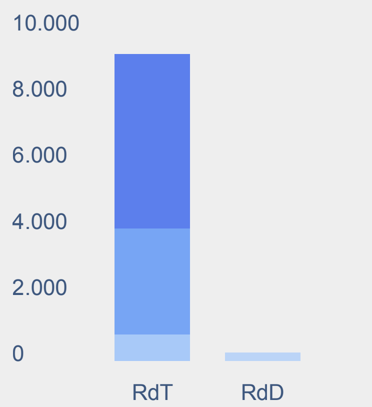
	RdT	RdD
Puesta en servicio	1.699	571
Con permisos	0	81
En curso	22	0
total	1.721	652

Hydropower



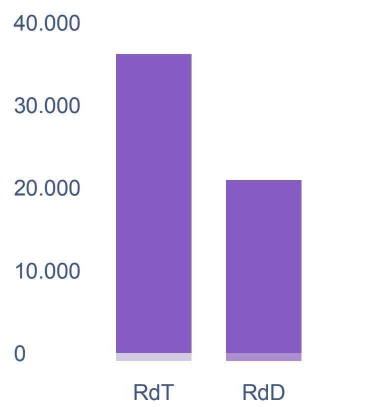
	RdT	RdD
Puesta en servicio	7.620	6.020
Con permisos	495	106
En curso	0	0
total	8.115	6.126

Pumped storage



	RdT	RdD
Puesta en servicio	5.380	0
Con permisos	2.733	0
En curso	1.196	154
total	9.309	154

Other technologies



	RdT	RdD
Puesta en servicio	36.188	6.373
Con permisos	128	671
En curso	568	178
total	36.884	7.222

RdD: Red de distribución **RdT: Red de transporte**

Puesta en servicio: generación en servicio

Con permisos: generación pendiente de puesta en servicio que cuenta con permisos de acceso y conexión a la red de transporte o aceptabilidad para conexión a la red de distribución

En curso: generación que ha solicitado permisos de acceso y conexión a la red de transporte o aceptabilidad para conexión a la red de distribución y actualmente se encuentra en curso

Source: Red Eléctrica de España, October 2024

8 New demands: data centers

A data center is a room or physical facility that houses IT infrastructure to create, run, and deliver applications and services. It also stores and manages the data associated with those applications and services.

The growth in data processing brought about by digital technologies has driven the proliferation of large and small data centers. During an initial phase, public and private entities equipped themselves with their own computing and processing resources. With the growth in blockchain computing needs, there was global growth in equipment dedicated to mining as a business whose basic input was energy and equipment amortization. The productive structure of this phenomenon was quite decentralized. Anyone who had cheap energy and the capacity to acquire equipment set up the business. The growth in energy consumption was not significant for the system.

The leap forward came with the massive introduction of artificial intelligence into all kinds of processes. Sam Altman, CEO of OpenAI, describes the objective progress as "surprisingly exponential and continuous." He compares it to the evolution of the iPhone, where no new model represented a major leap, but the leap from the first version to the latest has been extraordinary.

This consumption, together with cloud storage, explains why around 1.5% of the world's electricity is used to supply energy to data centers, equivalent to around 340 terawatt-hours (TWh), which could rise, according to other estimates, to 460 TWh in 2022. Most of this electrical energy is used for data storage and processing for all kinds of applications, from video streaming to financial transactions. However, artificial intelligence (AI) will account for a large part of the future demand for data centers.

At this stage of growth, data centers have become concentrated, some with extraordinary capacity and power, and there has been greater spatial concentration, as in the case of Ireland. One-fifth of the electricity consumed in Ireland is used to power the country's data centers, a figure higher than that consumed by its urban households. With one data center for every 42,000 inhabitants, Ireland has one of the highest concentrations of computing power per capita in the world.

There are currently around 60 data centers in Spain (owned by more than 40 companies). Increase in the surface area of data centers in the period 2023-2027 and increase in power of 52.7%. Madrid is consolidating its position as the main data center cluster in Spain, reaching a capacity of 110 MW (ranking sixth in the European market in the sector). A 54% increase in capacity was forecast for 2024 (an additional 58 MW). Barcelona is the second city with the highest concentration of data centers in Spain.

Microsoft has announced a regional cloud project between 2024 and 2025 (US$2.1 billion), including the construction of a new data campus in Villamayor de Gállego (Aragon). In the last six months, Spain has attracted €34.1 billion in investment for the construction of data centers, consolidating its position as a preferred destination in Europe for this type of infrastructure.

The cities of Zaragoza, Valencia, and Málaga are also concentrating data centers, but their combined size is smaller than the first two. In Zaragoza, there has been a conflict between developers, companies, and the administration on the one hand, and environmental groups on the other, who are protesting the water consumption and environmental impact of the centers, especially those planned by Microsoft and Amazon.

Forecasts for the coming years

The increase in data centers worldwide is generating a significant rise in energy consumption. In fact, the International Energy Agency estimates that global energy demand from data centers could increase by between 128% and 203% by 2030, potentially exceeding 1,000 TWh by that date, mainly due to AI-related energy consumption. These volumes are like Japan's total electricity consumption today. The growth is directly related to the rise of generative AI and other AI applications, which are driving unprecedented demand for computing power, compounded by growing demand for cloud services, streaming, social media, and other digital applications.

In the United States, for example, data center energy consumption is expected to account for nearly half of the growth in electricity demand between now and 2030. Ireland and the Netherlands also estimate very significant growth in the contribution of data centers to electricity demand over the next five years.

In China, electricity consumption by data centers is expected to double or triple by 2030 because of technological advances and the intense digitization of its economy. India, for its part, also expects significant growth in its computing and storage infrastructure, but on a smaller scale; while China could reach 600 TWh by 2030, it is unlikely that India will exceed 100 TWh by the same date.

In Spain, the Artificial Intelligence Strategy forecasts growth of 2,000 MW of installed power by 2030. In the last eight months, Spain has attracted investments worth €34.1 billion for the construction of data centers, consolidating its position as a preferred destination in Europe for this type of infrastructure.

Main projects announced:

- Meta (Facebook): €750 million in a data center in Talavera de la Reina (Toledo), generating 250 direct jobs.
- Blackstone (through QTS Data Centers): €7.5 billion in Aragon, with an estimated 1,400 direct jobs created during the construction and operation phases.
- DGNEX Data Centers (Dubai-based Damac group): €400 million for a data center in Vicálvaro (Madrid), with plans to expand in Barcelona and Zaragoza.
- Merlin Properties: €2 billion to develop a large European data center hub in Barcelona.
- Amazon Web Services (AWS): More than €15.7 billion in Aragón, with an estimated 17,500 jobs created and a contribution to GDP of €21.6 billion by 2033.
- Iberdrola: Global investments in data centers worth €10 billion, of which an estimated €2 billion will go to a large data center in Bilbao, in collaboration with Dominion and Kutxabank.
- Microsoft: €1.933 billion between 2024 and 2025 for a new cloud region in the Community of Madrid, with a projected contribution of €10.7 billion to Spanish GDP and around 77,000 new jobs over the next six years.
- Oracle: €920 million over the next ten years for a new cloud region in Madrid, located in two Telefónica data centers.
- Equinix: €52 million for the expansion of its data center in Hospitalet de Llobregat.
- Box2Bit (Capital Energy): €1 billion for a data center in Calatayud, in a 400,000-square-meter complex.
- Nabiax: €47 million to expand the capacity of its data centers in Alcalá de Henares and Julián Camarillo (Madrid).
- OVHcloud: Plans to install one of its five European zones in Madrid, with no details on the investment yet.

Despite the increase in consumption, improvements in the energy efficiency of data centers have helped to moderate the growth in demand in the past. However, these efficiency gains appear to have slowed in recent years.

9 Just Transition

1. Affected sectors

Fossil fuels, refineries, distributors

The scientific literature[2] has sufficiently demonstrated that the energy transition brings aggregate benefits in indicators such as employment and GDP. However, these benefits are not distributed evenly. Some sectors, especially those dependent on fossil fuels, could experience net losses, making them more vulnerable to economic impacts. These effects can spread to adjacent sectors, affecting local tax revenues and generating indirect repercussions on the local economy. The concentration of these effects in certain sectors and territories poses serious challenges of distributive justice and underscores the need to articulate policies that ensure a just transition for those sectors and territories. A central aspect of this disruption is the impact on employment resulting from the shift to a low-carbon economy. Environmental regulation tends to concentrate labor impacts on polluting industries, and although positive effects on overall employment are projected thanks to the creation of green jobs, these benefits often mask the fact that job losses may be highly concentrated in certain sectors.

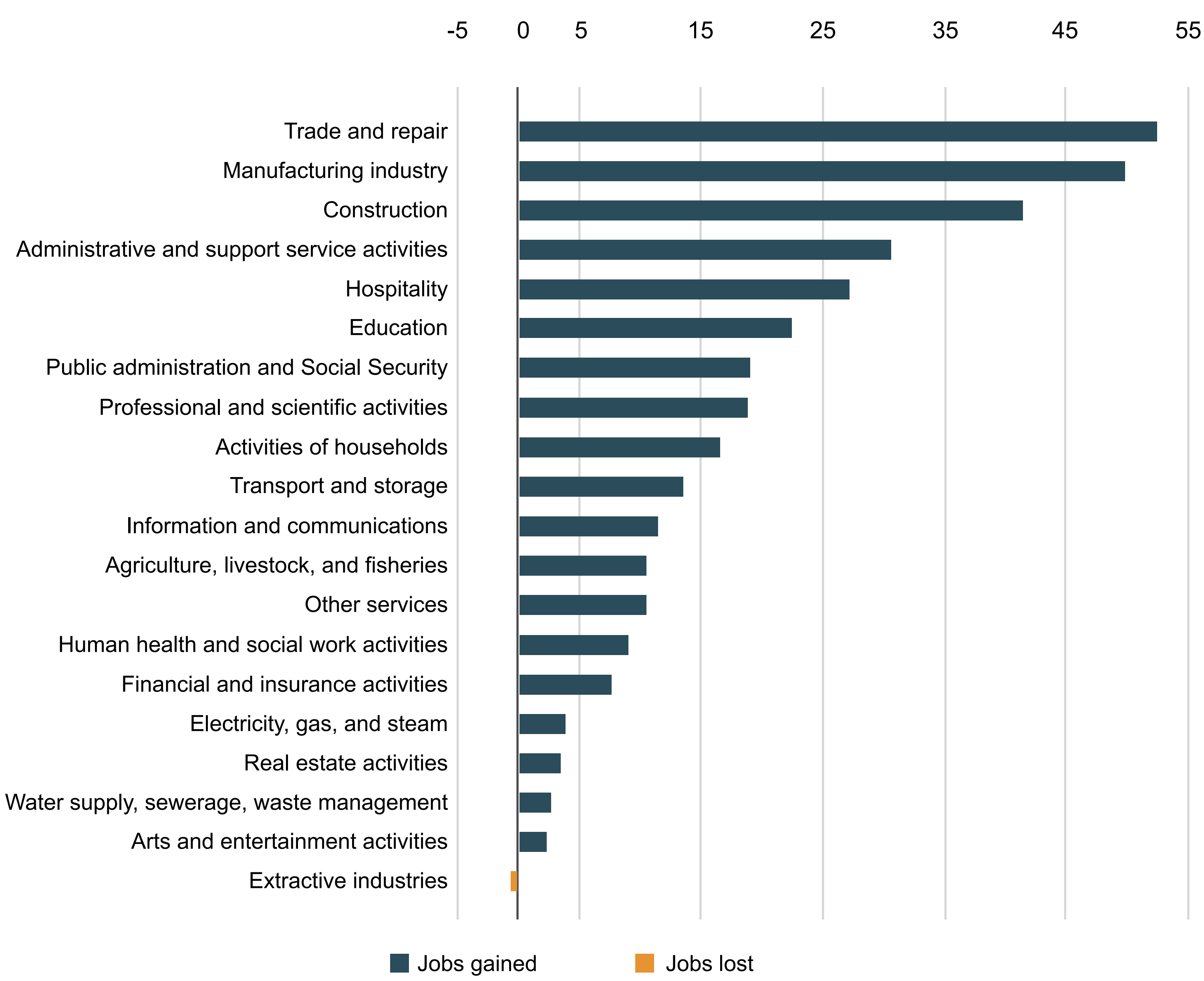
This situation has made it necessary to consider implementing measures that enable a "just transition" that protects vulnerable workers in the energy transition. This effort is essential not only from a social justice perspective but also to overcome the opposition of some groups that, concerned about job losses, have blocked climate and energy policies in the past.

Although there are not many studies on which sectors will be most affected by the energy transition in terms of employment or GDP, there is a clear consensus that it will be fossil fuel extraction activities (CNAE 0610, CNAE 0620), coking and oil refining (CNAE 1910, CNAE 1912), and gas transportation (CNAE 3521, CNAE 3522) that could experience the most significant net job losses as demand for fossil fuels declines and investment in renewable sources increases.

Other sectors, on the other hand, such as automobile manufacturing and its auxiliary industry, which are fundamental to the Spanish economy, will have to make significant adjustments to readapt their workforce to new propulsion systems, but it is likely that the net impact on employment will be less severe.

The report on "The economic, employment, social, and public health impact of the 2021-2030 Integrated National Energy and Climate Plan" itself points out that only the extractive industry will record net job losses in 2030, estimated at -569 jobs, due to the reduction in coal mining activity.

Impact on employment by sector (thousands of people/year)



Source: Economic, employment, social, and public health impact of the 2021-2030 National Integrated Energy and Climate Plan.

2. See bibliography: Grahan, K-Shultz, G. / IEA / World Bank

However, it says nothing about other sectors that will also be affected by the energy transition, and to which other studies attribute significant job losses that would be offset by job gains in other sectors such as solar energy (CNAE 3514), wind energy (CNAE 3519) and energy efficiency (CNAE 3521 and 3522).

Sectors of Activity (CNAE)	Estimated Change in Employment for 2050
Crude oil extraction (0610)	-25%
Natural gas extraction (0620)	-20
Electricity generation (fossil fuels) (3511)	-30
Solar energy (3514)	+15-20
Wind energy (3519)	+25
Energy efficiency (3521, 3522)	+10-15

Source: "Net Zero by 2050." International Energy Agency (IEA) and "Just Transition in the Coal and Other Fossil Fuel Sectors." World Bank

These estimates underscore the importance of just transition policies that support relocation and job training in emerging sectors. Studies also indicate that growth in sustainable jobs could offset losses in traditional sectors, although adaptation will require investment in new skills and support structures.

In Spain, sectors directly linked to the extraction, transformation, and distribution of fossil fuels will account for a total of 95 companies and 12,391 jobs in 2022, with most of the employment concentrated in oil refining companies (70%), which includes part of the employment in the distribution system.

Energy sectors	No. of companies	No. of workers
061 Crude oil extraction	6	7
062 Natural gas extraction	2	9
191 Coking plants	6	82
192 Oil refining	8	8,647
352 Gas production; distribution of gaseous fuels through pipelines	71	3,647
Total	**93**	**12,391**

Source: DIRCE. INE

According to the Spanish Association of Petroleum Product Operators (AOP), in 2022 there were a total of 12,346 points of sale, with the organization estimating that the sector generates around 200,000 direct, indirect, and induced jobs.

The energy transition will also affect occupations in the energy sectors in different ways. Some of those that will be most affected by the change by 2050, and which should be considered in a just transition, are:

- Crude Oil and Natural Gas Extraction (CNAE 0610, 0620): the occupations most affected are those of drilling and maintenance operators and technicians, for which a decline of up to 20-30% is projected in this subsector due to the fall in demand for fossil fuels.
- Electricity Generation from Fossil Fuels (CNAE 3511): in this case, the occupations most affected are thermal plant operators and technicians, and fossil fuel engineers. Job losses of around 25% are estimated as dependence on fossil fuel generation decreases, especially in countries committed to zero emissions.
- Gas Transportation and Distribution (CNAE 3521, 3522): the occupations potentially most affected are gas transportation and distribution technicians and operators, as the market is expected to stabilize or decline in the face of the shift to electricity and other renewable energy sources.

In short, both at the sector and occupation level, and regardless of the exact number of jobs lost as a result of the energy transition, for this transition to be fair, policies must be put in place to support these groups, reassigning workers from these sectors to other growing sectors, which in many cases will require significant professional retraining processes that must be accompanied by incentives to hire these workers.

2. Social sectors that reject renewables

A just transition must act on the groups that suffer harm in the process of restructuring the energy system to mitigate or reduce the damage. Those affected by changes in the productive structure that result in job and income losses have relatively well-oiled mechanisms at their disposal in the political and administrative machinery. However, the transition process involving the deployment of renewables has brought to light groups that feel harmed by these installations, and the appropriate measures are not being taken to respond to their demands and objections, which is affecting the pace of implementation.

The arguments of the groups that reject the deployment of renewables as it is currently being done refer to various issues. Some can be of general interest, such as the impact on biodiversity or damage to the food system, while others can be considered local issues.

The transition in rural areas takes on a different nature. Let us first review the groups that can be considered affected by the energy transition, which in this case correspond to those affected by the deployment of renewable energy generation facilities, basically wind and photovoltaic.

In the deployment of wind farms.

- Owners of forest land.
- Owners of agricultural land.
- Forest workers.
- Agricultural land workers.
- Groups and individuals who value visible biodiversity (mainly fauna, birds, and bats).
- Groups that value a landscape without highly visible and prominent mechanical devices.

In the deployment of photovoltaic panels

- Owners of agricultural land.
- Agricultural workers.
- Groups that advocate for locally sourced food.
- Groups and individuals who value visible biodiversity.
- Groups that value a landscape free of shiny metal and glass objects.

The correct approach to this issue requires territorial planning for the deployment of renewables that considers different criteria for the location of plants and seeks **to improve biodiversity**, protect soils of high agro-edaphological value, in addition to those that already enjoy environmental protection, and optimize the territorial integration of these new facilities. The most difficult problem to solve is how to deal with the impact on the landscape and the way in which certain groups perceive the intrusion of these new artifacts.

At the same time, it is advisable for renewable energy operators to become involved in **endogenous territorial development** projects within a framework of business investment with a return on the resources invested, or for the local population affected to be able to obtain direct economic benefits from the renewable energy facilities (such as cheaper electricity).

10 Circular economy of renewble energies

Wind turbines have transformed the traditional solution of capturing energy from a natural resource, the wind, into a contemporary technological solution. This machine that generates electricity requires many materials scattered around the world. The construction of photovoltaic panels also requires a significant effort in terms of mineral extraction, recycling, and treatment. In fact, there is a real risk of depletion of materials, energy, and economic resources.

It is estimated that for every MW of wind power, around 8 tons of waste are generated, mainly from blades and metal parts. In Spain, the generation of waste from wind turbine blades is expected to exceed 50,000 tons per year by 2030.

It is therefore very important to apply a strict approach to use based on proven needs and to rigorously apply the circular economy sequence:

1. Rigorously assess the need for facilities and reduce material consumption as much as possible, improving savings and efficiency.
2. Reuse and repair. The biggest obstacle to the reuse of panels is the lack of manufacturing in Europe. Reuse in wind turbines is achieved with greater power per

3. https://www.recyclia.es/panel-fotovoltaico-puede-reciclarse/

machine and with repowering, replacing machines with others of greater unit power. For batteries, reuse focuses on second life.

3. Recycle in the blade production process. The most advanced recycling technology, such as pyrolysis, allows the materials in the blades to be reused, although its implementation is still in the pilot phase in some plants.
4. Recover components for other production processes and other uses. The second option is to reuse and/or repair blades after the end of their useful life. In Europe, it is possible to reuse blades because there are manufacturing plants that could perform this task. Before rejecting any machine or main component, it is necessary to assess the option of repairing it, thus reducing waste generation.

1. Renewable generation. Photovoltaic panels

Photovoltaic panels contain a combination of materials such as glass (70-80%), aluminum, plastic, silicon, and small amounts of heavy metals (lead, cadmium, and tellurium). The separation and recovery of these materials is technically complex and costly, especially for materials such as silicon and rare metals.

An estimated 20-25 tons of waste per MW of photovoltaic installation is generated at the end of its useful life, mainly recyclable glass and aluminum. According to a study carried out by Recyclia[3], in collaboration with the company Recyberica Ambiental, for every ton of panels, the recoverable materials include approximately 750 kg of glass, 120 kg of metals (mainly aluminum and copper), and 20 kg of plastic.

2. Renewable generation. Wind turbines

Around 8 tons of waste per MW, mainly from blades and metal parts. Wind turbine blades represent the greatest challenge, as they are made of composite materials such as fiberglass and epoxy resins, which are difficult to recycle. The materials of greatest interest for wind turbine recovery are copper and aluminum.

There are several initiatives under study and some in the pilot phase, such as the Energy Technology Institute's project for recycling lithium-ion batteries, which is expected to achieve efficient recovery of both graphite and other non-active components, as well as the metals contained in the active material (cathode) of these batteries[4].

3. Batteries

Energy storage batteries can generate between 5 and 10 tons of waste per MW of installed capacity, depending on the design and life cycle[5].

Used batteries from electric vehicles can be treated, giving them a second life. In this regard, their potential use for stationary energy storage stands out. The accumulation of energy in batteries reduces the average cost of energy supply by storing energy during periods of low demand for use during times of high demand, providing more flexibility to the grid during peak tariff periods.

Thus, lower power requirements would help extend the useful life of batteries by up to 10 additional years. However, it should also be noted that the wide variability in the design, size, format, and electrochemistry of batteries on the market makes their treatment difficult and expensive.

In addition to reusing batteries, there is the possibility of recycling and recovering materials, particularly metals such as lithium, cobalt, manganese, and nickel, which are of high strategic value given the European Union's dependence on imports. Some studies predict high self-sufficiency rates for some of these metals if Europe manages to develop an industry capable of extracting them.

11 Barriers

The following are identified as the main barriers:

Energy system:

- Regulatory and fiscal uncertainty.
- Delays in electrical interconnections with France.
- Insufficient development of the electricity distribution network.
- Insufficient increase in the storage capacity of the electricity grid.
- Widespread implementation of frequency and inertia maintenance systems in renewables.
- Overflow of waste treatment capacity.

Building barriers:

- Lack of resources, technical capabilities, and personnel to tackle the energy renovation of buildings.
- Lack of demand aggregation tools.
- Lack of a financial architecture that mobilizes private investment and adapts to society's different borrowing capacities.
- Difficult management of community interventions in buildings, such as SATE.
- A problem whose solution requires multi-level coordination between financial institutions, the construction sector, energy companies, and public administrations.

4. This is the Recilion project. Source: https://www.ite.es/i-d-i/proyectos/recilion/
5. Recilion project. Source: https://www.ite.es/i-d-i/proyectos/recilion/

Mobility barriers:

- Low acceptance of electric vehicles among private vehicle owners.
- Challenges in changing consumer behavior and perceptions of transportation.
- High cost of electric vehicles and the format of reimbursable subsidies instead of direct purchase subsidies.
- Low level of development of the battery charger network on the road network.
- High administrative complexity and lack of institutional coordination for the installation of charging points.
- Negative impact on employment and the automotive industry, which weigh heavily on decisions to accelerate the replacement of combustion vehicles with electric vehicles.
- Lack of non-fossil fuels suitable for heavy transport and certain industrial uses.
- Lack of a comprehensive strategy for the design and integration of interurban public transport services that can compete with private vehicles in terms of price and versatility.

Industry barriers:

- Insufficient availability of resources and skills to electrify the industry.
- Technical limitations in solutions for different types of industry.
- High investment costs.
- Technological difficulties in decarbonization in some sectors, and the technological maturity and price differential of hydrogen compared to other energy resources.

Barriers to the deployment of renewables:

- Current weakness in demand, combined with insufficient international connection with France.
- Problems with social acceptance of the deployment of renewables at the local level and in nearby urban environments.
- The bureaucratic complexity of processing authorizations and the lack of technical resources in the environmental assessment administration.
- Lack of political and administrative will in the administrative processing of environmental assessments in some autonomous communities.
- Uncertain availability of investors in different components of the system, especially in generation and storage.
- Resistance from electricity companies that own nuclear power plants to comply with the closure program. If the share of nuclear energy in the energy mix were to be extended, it would be at the expense of a reduction in the share of renewable generation, which is perfectly viable in combination with storage.
- Reactionary against renewables and the ecological transition (after the blackout, the fires, the DANA, etc.) with the capacity to permeate part of public and political opinion.

12 Fossil fuel consumption dynamics

Evolution of fossil fuel consumption over the last ten years

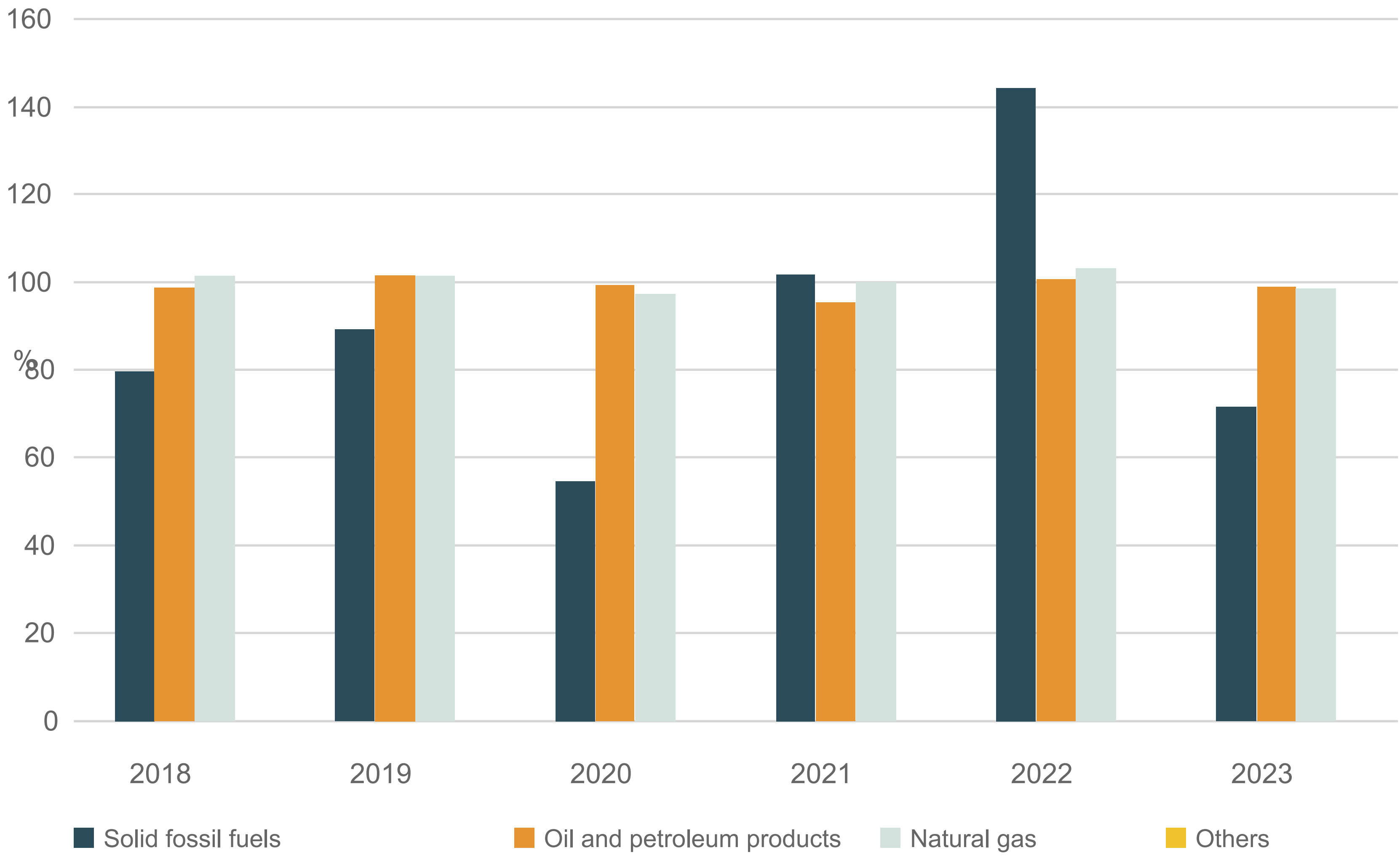
The energy system is based (70%) on petroleum products and natural gas for non-electrical uses. The positive figures for the implementation of renewables for electricity generation have had no effect on reducing fossil fuel consumption. In transport, both diesel (+0.7%) and gasoline (+7.5%) consumption increased in 2024 compared to 2023. The introduction of measures to reduce fossil fuel consumption in buildings is very slow, and industries are slowing down their conversion to electrified systems. As an aggregate result of these dynamics, both petroleum and gas consumption have maintained their annual sales figures, even showing slight growth. Gas consumption has risen by 1.8% on average over the last five years compared to the previous five years. Petroleum consumption increased by 4% in the last year (2023-2024).

Energy dependence on fossil fuels represents an annual cost of around €65 billion. This amount affects the perception of Spanish debt in the markets, and reducing it would lower the cost of issuing bonds. Reducing our imports would also reduce our risk as a country, which would be reflected in both the risk premium and the cost of financing our public debt. These financial benefits would be accompanied by economic benefits due to the general reduction in energy prices and the reduction in emission rights costs.

The role of fossil fuels

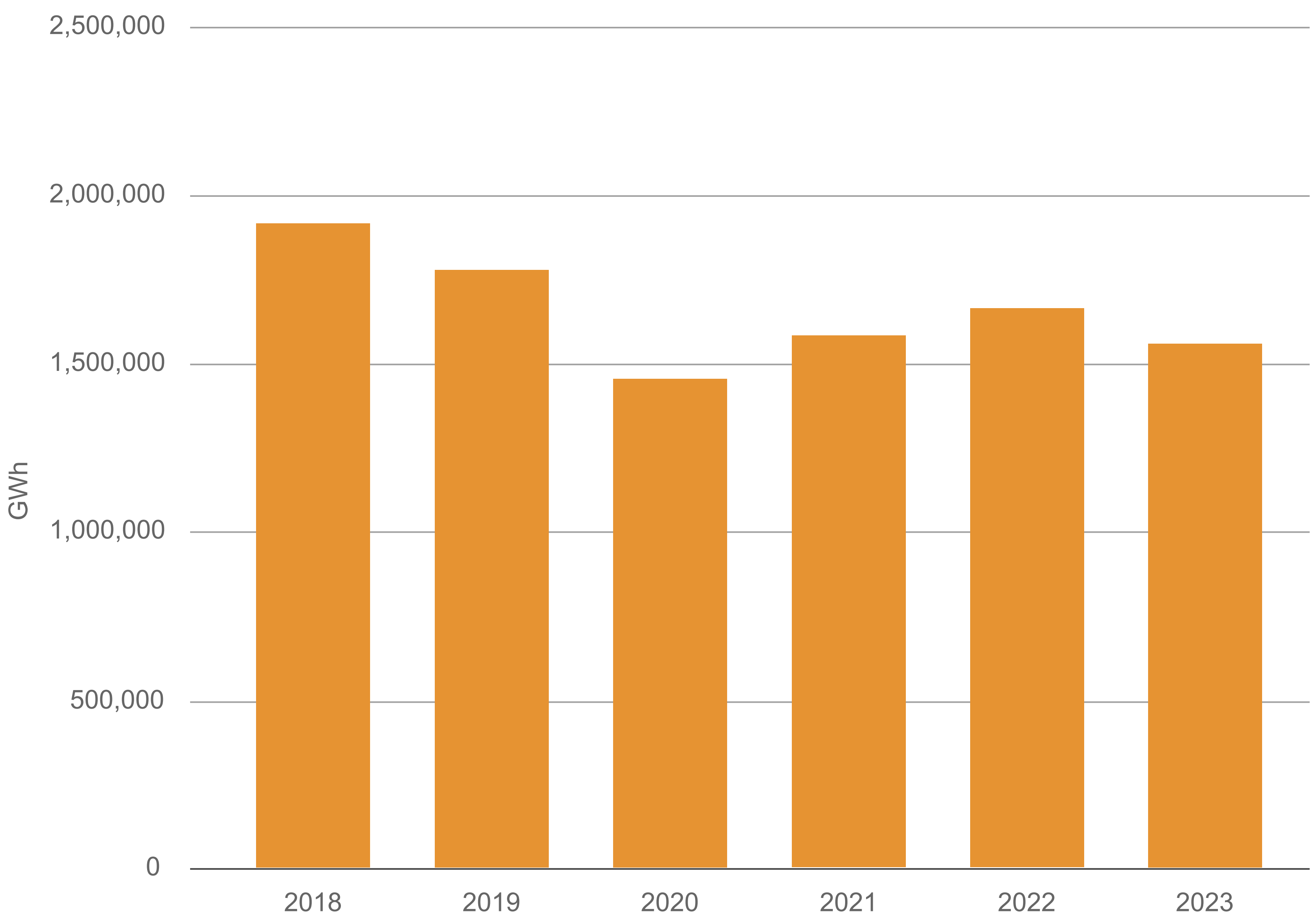
Spain's energy dependence stood at 68.6% in 2023, meaning that it relies heavily on external energy sources to meet its energy needs, particularly through imports of oil, natural gas, coal, and other non-renewable energy sources. This is because certain sectors, such as industry, transport, and heating, continue to grow and require large amounts of fossil fuels. As discussed in this report, there is an urgent need to electrify those industries that can do without fossil fuels in the short term, as well as mobility and heating in homes and buildings. This will reduce Spain's energy dependence.

Annual evolution of fossil fuel dependence by energy source (%)



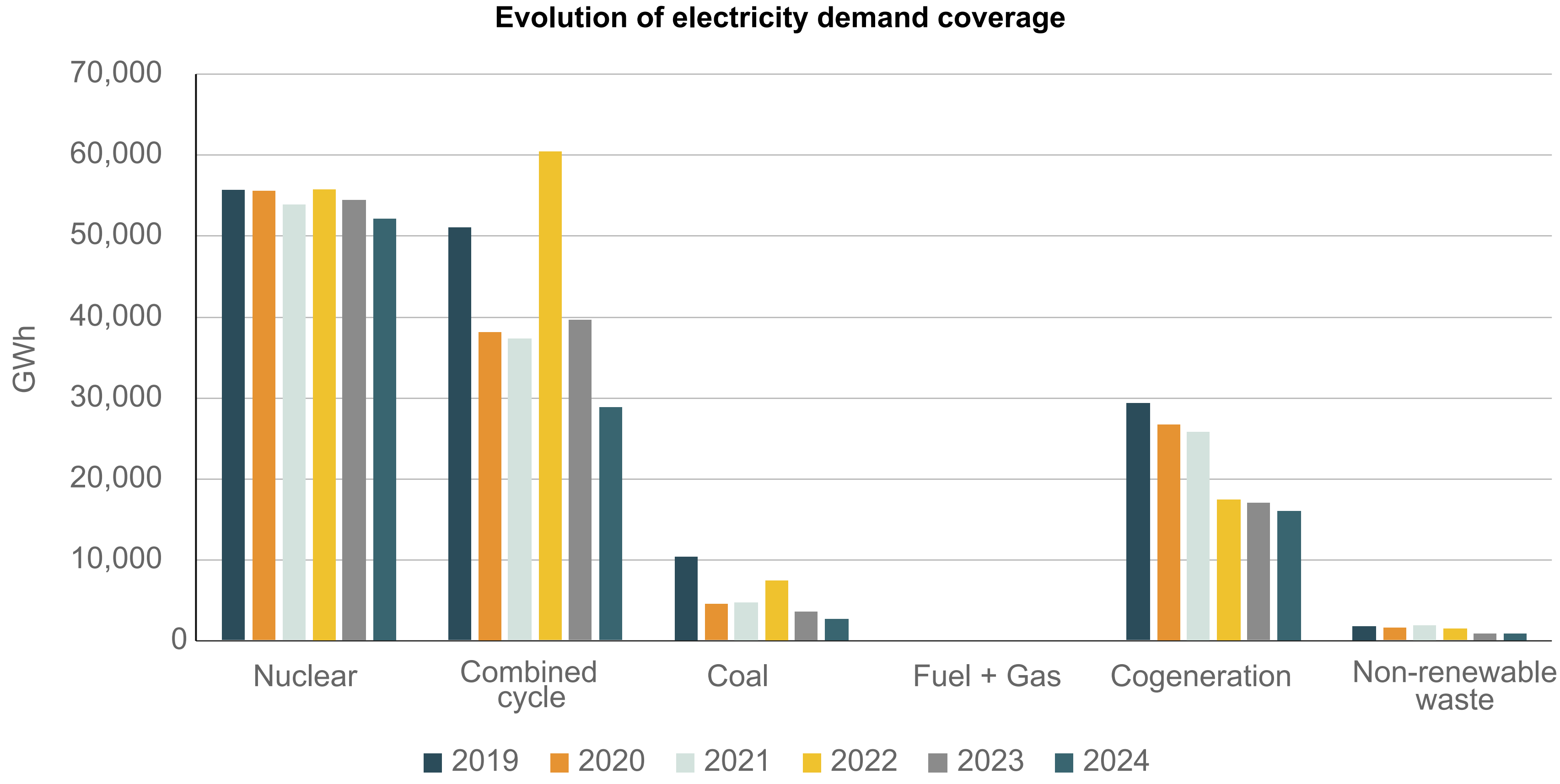
Source: INE, 2025

Evolution of gross domestic energy consumption generated by non-renewable sources



Source: Energy Balance of Spain 1990-2023, 2025

In the last five years, electricity demand has been met with less reliance on non-renewable energy sources, falling by 32% in 2024 (101,989 GWh) compared to 2019 (149,290 GWh). This is due to the boost received by renewable energies, which have enabled them to reach 56.8% of energy generation.



Source: Red Eléctrica, 2025

13 Energy as a security factor

In the context of the European Council meeting on March 20, 2025, the role of energy in defense and rearmament strategy emerged as a crucial issue. Below is a summary of the statements made by European leaders:

- **Need for energy autonomy:**
  - The importance of reducing dependence on fossil fuels, especially from external suppliers, to strengthen European security has been emphasized.
  - Leaders have highlighted the need to accelerate the transition to renewable energy sources and diversify energy supply sources.

- **Investment in renewable energy:**
  - Investment in renewable energy technologies has been promoted as an integral part of the defense strategy, recognizing their role in reducing energy vulnerability.
  - The EU has been urged to lead the technological leap in defense, where renewable energies play a key role.

- **Energy supply security:**
  - Leaders have expressed concern about energy security, especially in the context of geopolitical tensions.
  - The need to protect critical energy infrastructure from potential attacks has been highlighted.

- **Relationship between energy and defense:**
  - The close relationship between energy security and defense has been recognized, as energy dependence can be used as a geopolitical weapon.
  - The need to reduce this dependence has been expressed so that Europe can become more autonomous in the defense sector.

In summary, European leaders have recognized the fundamental role of energy in defense and rearmament strategy, highlighting the need for greater energy autonomy, investment in renewable energies, and the protection of critical energy infrastructure.

Some of their most relevant statements are summarized below:

Pedro Sánchez, President of the Government of Spain:

Sánchez stressed the need for the European Union to improve its technological capabilities in defense, rather than focusing solely on the accumulation of weapons. He expressed concern about the use of the term "rearmament" and advocated for a different perspective that includes European security and defense capabilities. He also highlighted that Southern European countries face different challenges, such as strengthening border controls and combating terrorism and cyberattacks.

Ursula von der Leyen, President of the European Commission:

The president has set 2030 as the target date for completing the European rearmament project, seeking to make the continent autonomous in defense and give it a credible deterrent capability against Russia. She has emphasized the need for a strong defense industrial base and urged member states to increase their spending in this area, citing Germany as an example. Although defense spending has grown by 31% since 2021, she considers it still insufficient compared to the United States, Russia, and China.

Dan Jorgensen, European Commissioner for Energy and Housing:

Jorgensen revealed that EU purchases of Russian gas since 2022 have contributed significant funds to the Kremlin's "war chest," equivalent to the cost of 2,400 F-35 fighter jets. He emphasized the urgency of ending these imports and set a target of eliminating Russian gas by 2027. Although imports have fallen from 45% in 2022 to 13% today, the EU's official strategy for achieving this energy independence has been delayed. Jorgensen stresses the importance of diversifying energy supplies and continuing the transition to green energy.

Jean-Claude Juncker, former President of the European Commission:

Juncker has harshly criticized the Trump era, comparing its impact on Europe to past crises such as the euro and the refugee crisis. He argues that Trump seeks to divide Europe but will fail again. He stresses that Europe must strengthen its security without relying on the US, especially after Russia's invasion of Ukraine. He advocates for a common European defense and institutional-level security cooperation. He criticizes centrist parties' alliances with the far right and highlights the importance of concepts such as security, protection, and pride in the European dictionary to counter populism.

Keir Starmer, Prime Minister of the United Kingdom:

Starmer has stated the need to plan a future security strategy for Ukraine, arguing that Russian President Vladimir Putin will breach any peace agreement without protective measures. During a visit to Northwood Barracks, he emphasized that effective security mechanisms are required to achieve lasting peace and a secure and sovereign Ukraine. He also mentioned that any international force deployed in Ukraine would be to monitor and protect strategic enclaves, not to maintain peace.

These statements reflect a growing awareness among European leaders of the interrelationship between energy, security, and defense in the continent's strategy.

OIL IMPORTS BY COUNTRY

Over the last decade, Spain's oil supply has undergone significant changes in terms of supplier countries. The most relevant trends are highlighted below:

The evolution of oil supplies to Spain over the last ten years has undergone significant changes, influenced by geopolitical and economic factors and the energy transition. Here is a summary of the most notable trends:

Diversification of sources:

- Spain has sought to diversify its sources of supply to reduce its dependence on single suppliers and mitigate geopolitical risks.
- This has led to an increase in imports from North and South America, along with continued imports from Africa.

Changes in major suppliers:

- The United States has gained prominence as a key supplier, driven by increased oil and gas production.
- South American countries, such as Brazil, have increased their share of oil supplies to Spain.
- Africa remains a very important supplier for Spain.
- There have been fluctuations in imports from Middle Eastern countries, influenced by oil price volatility and geopolitical tensions.

Recent trends:

- In recent years, there has been an increase in supply volatility due to international geopolitical instability.
- The transition to renewable energy sources is beginning to influence oil demand, although oil remains a key energy source for Spain.

Sources of information:

- The Strategic Petroleum Products Reserve Corporation (CORES) provides detailed data on oil imports to Spain, allowing for in-depth analysis of long-term trends.

In summary, oil supplies to Spain have evolved towards greater diversification of sources, with an increase in the importance of suppliers such as the United States and Brazil. However, geopolitical volatility and the energy transition are generating continuous changes in the Spanish energy landscape.

Diversification of suppliers:

- **United States:** Oil imports from the United States have grown significantly. In 2019, they accounted for less than 3% of Spain's total imports, while in 2024 they reached 16%, representing an increase of 437% over this period.

- **Venezuela:** After a decline in previous years due to sanctions and restrictions, imports of Venezuelan crude oil doubled in 2024, reaching three million tons, 116% more than the previous year.

Decreased dependence on OPEC:

Imports from member countries of the Organization of Petroleum Exporting Countries (OPEC) have decreased by 41% since 2019. In 2024, these countries accounted for 36% of Spain's oil imports, compared to 60% in 2019.

Main suppliers in 2024:

In 2024, the main oil suppliers to Spain were:

- **United States:** 16% of total imports.
- **Nigeria:** 11%.
- **Mexico:** 13%.
- **Brazil:** 16%.
- **Libya and Saudi Arabia:** Each contributed around 6% of total imports.

Recent trends:

In November 2024, oil imports increased by 14% compared to the same month the previous year, reaching 5.47 million tons. Mexico was the main supplier with 941,000 tons, followed by Brazil and the United States.

These changes reflect Spain's strategy of diversifying its oil supply sources, reducing its dependence on traditional suppliers and adapting to the dynamics of the global energy market.

In 2014, crude oil imports in Spain were distributed among several supplier countries. Although exact data for that year is not available in the sources consulted, the following trends can be highlighted:

- **Mexico:** Remained one of Spain's main suppliers of crude oil.
- **Nigeria:** It occupied a prominent position as an oil supplier.
- **Russia:** It was also one of the main exporters of crude oil to Spain.

In addition, imports from member countries of the Organization of Petroleum Exporting Countries (OPEC) increased by 15.6% compared to the previous year, accounting for 56.7% of total crude oil imports in 2012.

14 Debate on the extension of nuclear power plants

1. Global and European context

The nuclear option is one of the most controversial issues worldwide when it comes to energy. While some countries continue to rely on this source of generation, others are abandoning it completely due to safety risks, costs, and a commitment to renewables.

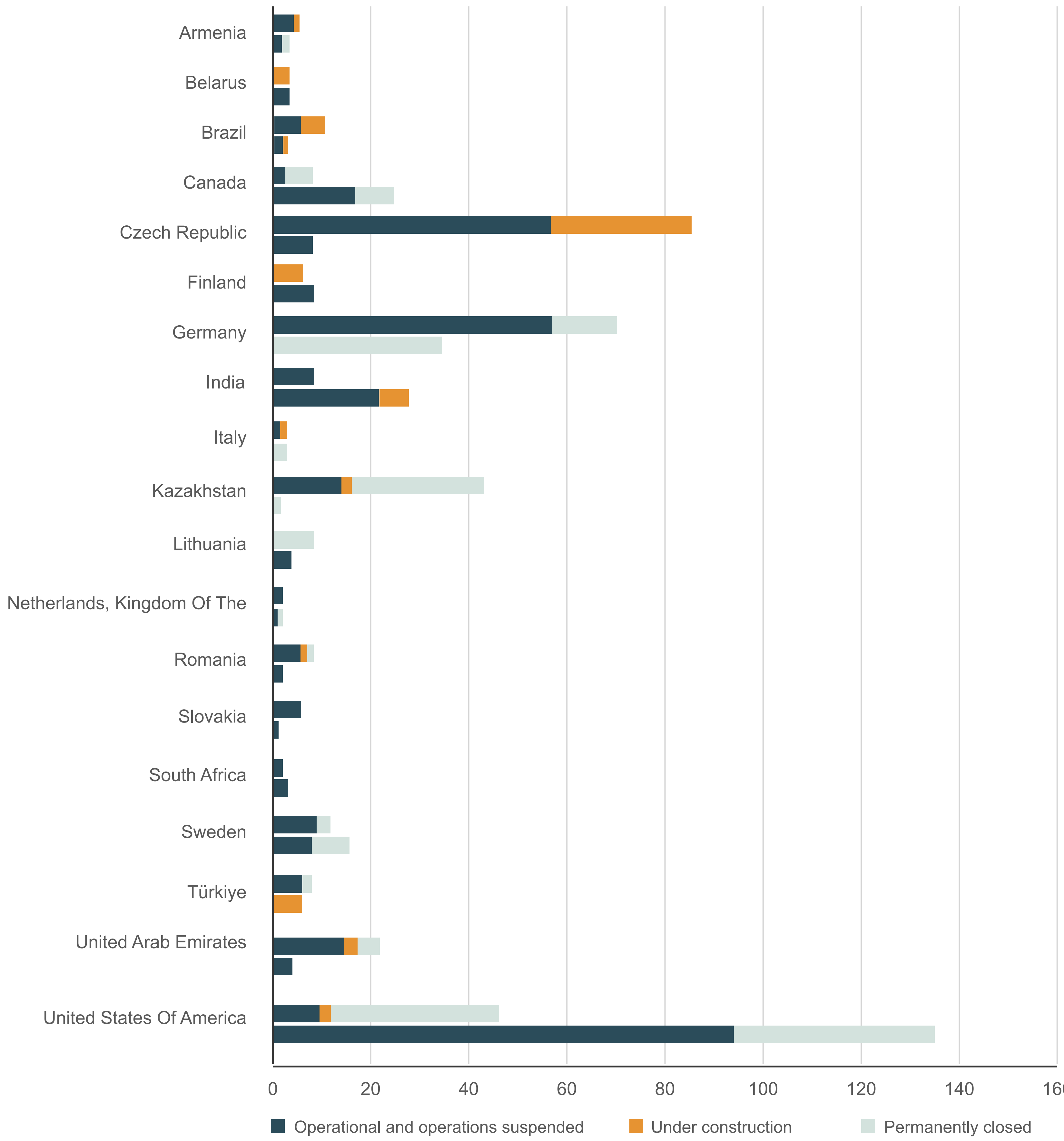
According to the Nuclear Reactor Information System, managed by the International Atomic Energy Agency (IAEA)[6], there were 417 nuclear reactors in operation worldwide in April 2025, as well as 23 reactors that were shut down. The European Union has 100 of the 440 reactors in operation and shut down worldwide.

In addition, 61 reactors are under construction in 15 countries, including China (28), India (6), Egypt, Russia, and Turkey (4 in each country). Of those 61 reactors under construction, only one is in a European Union country (Slovakia).

However, as mentioned above, there is a growing trend toward the closure and dismantling of nuclear power plants in countries around the world. The most notable case is that of Germany, which closed all its plants in 2023, but it has not been the only country to do so (Lithuania also closed its plants after agreeing to join the EU). Other countries such as the US, the UK, Japan, France, and Italy have closed or intend to close several nuclear reactors in the coming years, although in these cases there is no apparent desire to abandon nuclear energy (new reactors have recently been built, are under construction, or are planned).

6. https://pris.iaea.org/PRIS/home.aspx

Number of reactors and their current status, by country



Source: Nuclear Reactor Information System, managed by the International Atomic Energy Agency (IAEA), 2025

Traditionally, the debate on nuclear energy in Spain has been intense, with different political parties and organizations holding divergent positions. Some politicians and anti-nuclear groups advocate the closure of nuclear power plants, while others defend their maintenance and the construction of new facilities. These positions have persisted over time until the present day, but the "expiration date" of the oldest nuclear power plants, set at 40 years, coupled with the pursuit of energy independence, has sparked interest in providing more accurate technical, economic, and environmental arguments, whether for or against this alternative.

Status of nuclear reactors in Spain		
FUNCIONAMIENTO	**BAJO CONSTRUCCIÓN**	**CIERRE PERMANENTE**
7.123 MW(e) Capacidad Neta Total	**0 MW(e)** Capacidad Neta Total	**1.067 MW(e)** Capacidad Neta Total
7 Reactores de Energía Nuclear	**0 Reactores de Energía Nuclear**	**3 Reactores de Energía Nuclear**

Source: Nuclear Reactor Information System, managed by the International Atomic Energy Agency (IAEA), 2025

There are currently seven nuclear reactors in operation in Spain, making it the tenth country in the world and the second in Europe with the highest production capacity (7 GW): Almaraz I and Almaraz II (owned by Iberdrola, Endesa, and Naturgy), Ascó I (Endesa) and Ascó II (Endesa and Iberdrola), Cofrentes (Iberdrola), Vandellós II (Endesa and Iberdrola), and Trillo (Iberdrola, Naturgy, EDP, and Endesa).

According to the PNIEC scenario, for the period 2021-2030, a 4 GW decrease in installed nuclear power is expected (power corresponding to four of the seven reactors currently in operation). This decrease is part of the plan for the orderly, phased, and flexible decommissioning of the existing nuclear reactors, which provides for the decommissioning of the other three reactors between 2031 and 2035. The first plant agreed for decommissioning is Almaraz (2027), while the last one planned is Trillo (2035).

Likewise, the Seventh General Plan for Radioactive Waste (7th PGRR, hereinafter), approved in December 2023, is in line with the PNIEC and envisages a scenario that includes:

- Cessation of nuclear power plant operations between 2027 and 2035. According to the 6th PGRR, the definitive shutdown of the plants currently in operation would have taken place, after 40 years of service life, between 2021 and 2028.
- Start of the decommissioning of nuclear power plants three years after their definitive shutdown, except for Vandellós I (shut down since 1989 due to a serious accident), whose final phase will be carried out from 2030 onwards.
- Continuation of the operation of the El Cabril storage center (Córdoba) for medium, low, and very low-level waste until the decommissioning of the plants is complete, as already planned in the 6th PGRR.
- Continuation of actions to expand the capacity of the Individualized Temporary Storage Facilities (ATI) for spent fuel in nuclear power plants, allowing for their operation and decommissioning, as already planned in the 6th PGRR.
- Commissioning of seven Decentralized Temporary Storage Facilities (ATD) at nuclear power plant sites for spent fuel and high-level waste until its transfer to final storage. The DTL at each plant will consist of its TSI plus a new complementary facility or additional measures to enable maintenance operations to be carried out on the containers in which spent fuel is stored when the plant ceases to be operational.
- Final storage of spent fuel and high-level waste in a Deep Geological Repository (DGR), which is the technical solution already envisaged in the 6th PGRR and which has been chosen by the most advanced countries in this field. The 7th PGRR establishes a roadmap for Spain to have a DWS, ensuring a prior process of public information and participation, like those developed in European countries that have already decided on the location of their DWS, such as Finland, Sweden, Switzerland, and France.

2. Main factors involved in the debate

The closure of nuclear power plants in recent decades has been due to a combination of technical, economic, political, social, and environmental reasons. These factors and some examples are identified below:

- Safety and aging of facilities. Many closed plants were old (more than 30-40 years old) and keeping them operational involved high modernization costs. Example: Fessenheim (France) closed in 2020 after 42 years due to its age, despite being operational.

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- Safety and aging of facilities. Many closed plants were old (more than 30-40 years old) and keeping them operational involved high modernization costs. Example: Fessenheim (France) closed in 2020 after 42 years due to its age, despite being operational.
- Economic reasons: in several countries, nuclear power cannot compete with cheaper renewables (solar, wind) and natural gas. Example: Indian Point 3 (USA, 2021)

Arguments for and against the extension of nuclear power plants

Main arguments in favor	Main arguments against
Low greenhouse gas emissions	Accident risk
High energy density	Radioactive waste
Energy security	High construction and safety costs
Technological development	Higher maintenance costs than renewables
Increase in electricity system costs if renewables do not meet demand	Decrease in electricity system costs if renewables meet demand
High levels of employment	Social and economic concerns
Existing infrastructure, with investment required only for modernization	Maintaining nuclear power slows the deployment of renewables
Limited current development of energy storage	Feasibility of meeting demand entirely with renewables

Source: Own elaboration, 2025

15 Relevant actors

Companies and public and private organizations whose main activity has an impact on energy savings and efficiency play a fundamental role in the energy transition. In this regard, those actors in the renewable energy sector are particularly relevant.

Below is a list of some of the main players in the sectors pursuing a just transition (in addition to many other regional or subregional public bodies, private entities, energy producers, and component manufacturers' associations, which are not specifically mentioned). The list below is not intended to be exhaustive, but rather to illustrate the diversity and importance of the players involved in the energy system:

- Spanish Association of Fuel and Combustible Retailers (AEVECAR)
- Energy and Territory Alliance (ALIENTE)
- Association of Spanish Energy Management Agencies (EnerAgen)
- Spanish Shippers Association (ACE)
- Association of Energy Efficiency Companies (A3E)
- Association of Electric Power Companies (AELEC)
- Association of Renewable Energy Companies (APPA)
- Association of Comprehensive Maintenance and Energy Services Companies (AMI)
- Association of Heating and Cooling Network Companies (ADHAC)
- Association of Wind Energy Developers and Producers of Andalusia (APREAN)
- Association of Liquid Terminals (ATliq)
- International Road Transport Association (ASTIC)
- Wind Energy Business Association (AEE)
- Business Association for the Development and Promotion of Electric Vehicles (AEDIVE)
- Spanish Association of Eco-Friendly Vehicles (AEAE)
- Spanish Biogas Association (AEBIG)
- Spanish Cogeneration Association (ACOGEN)
- Spanish Energy Law Association (AEDEN)
- Spanish Association for Home Automation and Building Automation (CEDOM)
- Spanish Association of Automobile and Truck Manufacturers (ANFAC)
- Spanish Association of Automotive Professionals (ASEPA)
- Spanish Association of Natural Gas for Mobility (GASNAM)
- Spanish Association of Liquefied Petroleum Gas Operators (AOGLP)
- Spanish Association of Petroleum Product Operators (AOP)
- Spanish Association of Automotive Suppliers (SERNAUTO)
- Spanish Bioethanol Association (Bio-e)
- Spanish Gas Association (SEDIGAS)
- Spanish Hydrogen Association (AeH2)
- Liquefied Gas Association (AGL)
- National Association for Energy Saving and Efficiency (ANAE)
- National Association of Energy Services Companies (ANESE)
- National Association of Photovoltaic Energy Producers and Investors (ANPIER)
- Association for Energy Transition (ATE)
- Solar Thermal Industry Association (ASIT)
- Spanish Technical Association of Air Conditioning and Refrigeration (ATECYR)
- AEICE Cluster
- Autonomous communities: regional agencies and bodies for energy, renovation, and climate change
- Autonomous communities: environmental assessment services
- Spanish Confederation of Service Station Entrepreneurs (CEEES)
- Spanish Bus Transport Confederation (CONFEBUS)
- Spanish Confederation of Freight Transport (CETM)
- National Confederation of Diesel Distributors (Codigasoil)
- Electricity distribution companies. The main ones are: Endesa, Iberdrola, E-Redes Distribución (EDP Group), Unión Fenosa (Naturgy), Viesgo Distribución (EON); but there are more than 300 small distributors also known as independents.
- Companies involved in recycling initiatives: Greening Relive, EnergyLOOP, Iberdrola, Naturgy, EDP, FCC, Acciona, SungEel Hitech, GDV Mobility, IBERSYD, and PV Cycle.
- Eurecat.
- Spanish Nuclear Industry Forum.
- Renewables Foundation.
- Green Building Council Spain (GBCE)
- Spanish Coal Group (GEC)
- Energy Technology Institute.
- Spanish Geothermal Technology and Innovation Platform (GEOPLAT). In 2024, it launched its spin-off: Spanish Geothermal Association (GEOENERGIA)
- Platform for a New Energy Model (Px1NME)
- Spanish Photovoltaic Technology Platform (FOTOPLAT)
- Spanish Electricity Network
- SOLARTYS
- Tecnalia.
- Union of Independent Oil Workers (UPI)
- Spanish Photovoltaic Union (UNEF).

16 Dynamics. Opportunities and uncertainties

1. A new step towards the renewable energy + storage electricity model

The generation mix of the Spanish electricity model has recently fluctuated between a greater or lesser share of nuclear and combined cycle gas power and a greater share of renewables. The consequences of the blackout that took place on April 28, 2025, have played a significant role in this debate.

What do we know about the blackout on April 28 and how does it influence the future of the energy system?

According to the ENTSO-E report , the main cause of the blackout in Spain and Portugal on April 28 was a "surge cascade" (high voltage).

This event was described as "unique in the world" and the most serious incident in the European electricity system in more than 20 years, as the collapse was caused by an uncontrolled increase in voltage, rather than the "classic" reason of low voltage.

The report is factual in nature, describing events, without attributing blame or identifying a root cause. The investigation is ongoing, and the panel will publish causal conclusions in the final report.

It is important to note that according to the report, the blackout was not caused by an "excess of renewables"; the focus is on voltage control problems and how generation responded/acted under those conditions . It is also worth noting that the report ruled out the causality of frequency control inertia, which was widely discussed in the media in the weeks following the blackout.

Failures in voltage control and regulation

The report highlights problems in controlling system voltage:

- **Insufficient mechanisms:** Existing voltage control mechanisms were unable to control the rapid voltage variations that occurred.
- **Conventional generation:** It was found that conventional generation facilities in Spain did not control the system voltage as planned.
- **Limitation of renewables:** Renewable energy facilities (solar and wind), despite being technically prepared, were unable to participate in voltage regulation because the operating procedure (Spanish PO 7.4, dating from 2000) was not updated at that time to allow their active contribution to voltage control.

Immediate triggering factors

The process that led to the "overvoltage cascade" included:

- **Previous oscillations:** Local voltage and frequency oscillations occurred. The measures taken by operators (such as reducing flows with France) to mitigate them, although protocol-based, further increased the voltage in the Iberian system.
- **Massive generation disconnections:** The surge peak caused the sudden disconnection of approximately 2,200 to 2,500 MW of generation, mainly renewable plants (wind and solar) in southern Spain (Andalusia, Extremadura, etc.), starting at 12:32 p.m., due to their high-voltage protection systems.
- **System defense failure:** Automatic defense mechanisms (such as load shedding) were activated, but were not sufficient to contain the collapse.

Initial consequences for the energy system

- It has sparked public debate on the electricity system model, highlighting the viability of a model based on renewables and storage.
- In the short term, it is hampering the pace of renewable energy penetration and deployment due to uncertainties and REE's operation favoring conservative options (combined gas cycles). The operation of wind and photovoltaic management companies is deteriorating and deterring new investors.
- It has boosted interest in grid storage, both in hybridization solutions and specific installations.
- It creates the need to address voltage control regulation and remuneration as soon as possible, incorporating renewable generation into the stabilizing function.

2. Hydrogen from renewables as fuel for heavy traffic mobility and industry

Replacing the fossil fuels currently used for land, sea, and air transport vehicles is an unresolved challenge. In this research and development effort, green hydrogen is attracting the greatest interest from all types of agents and especially from public programs in many different countries. This same fuel is the preferred candidate to replace fossil fuels in the chemical industry, or in some industrial sectors that consume more energy at high temperatures (such as steel and cement), aviation, and maritime transport.

The Spanish government has approved the "Green Hydrogen Roadmap," which states that "it is positioned as one of the main energy vectors in the long term because its production and consumption are climate neutral and do not generate polluting emissions. Unlike other renewable energy sources, hydrogen can be stored as pressurized gas or in liquid form, allowing for greater manageability.

This document identifies the following opportunities:

- Eliminating pollutant and greenhouse gas emissions into the environment
- Developing the value chains of the hydrogen economy and positioning Spain as a technological leader.
- Enabling the penetration of a higher percentage of renewable energies into the electricity system, promoting a greater degree of manageability.
- Reducing national and European energy dependence.
- Making Spain one of the European leaders in renewable energy generation.
- Promote the decarbonization of isolated energy systems, with special attention to island territories.
- To promote Spanish energy R&D&I.

The program has ambitious objectives that are conditional on overcoming the price differential that exists with the technology available to date. It would be necessary to achieve a maturing evolution of the process of obtaining green hydrogen, its transport, and distribution under viable and safe conditions for these objectives to be achieved. The current situation is one of technological uncertainty.

3. New ways of meeting energy needs and new forms of needs with the available energy

It is likely that all the efforts applied to the different components of the system will not be sufficient to decarbonize the energy system built over decades with fossil fuels as its backbone. This means that it will be advisable to review the foundations of the well-being provided to citizens and the energy foundations of the productive system.

In this sense, the application of the principles of "connected self-sufficiency" and "proximity" provide new foundations for the organization of society and the satisfaction of needs and aspirations. The first condition is to have the necessary resources available, especially renewable energy in its various forms, and based on an assessment of availability, to build a system of well-being and production, adding to this the contribution of the rest of the planet and balanced exchange relationships. The current level of globalized exchange of goods and services is difficult to maintain in a scenario of fossil fuel scarcity.

When talking about transition, it is necessary to take this horizon into account, because it is not just a matter of electrifying to integrate a huge volume of energy generated by renewable technologies. It is a matter of evolving towards a global system without fossil fuels or with a reduced contribution, and this implies a change of model and structure.

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