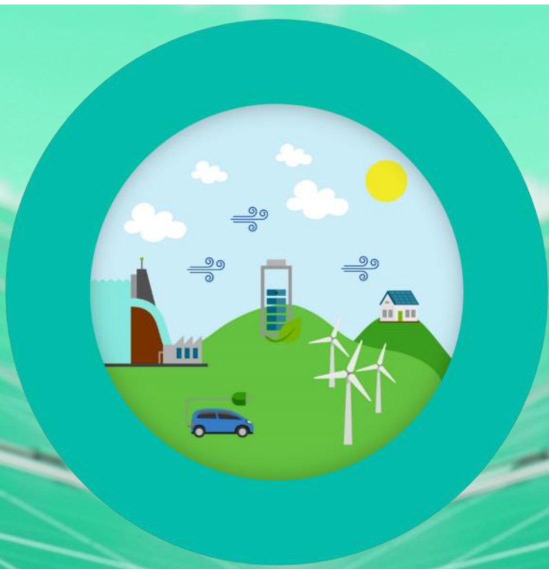

DRAFT STRATEGY FOR STORAGE ENERGY

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GOBIERNO DE ESPAÑA
VICEPRESIDENCIA CUARTA DEL GOBIERNO
MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA Y EL RETO DEMOGRÁFICO

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EXECUTIVE SUMMARY

The transition to climate neutrality implies a profound transformation of the energy system, which will be fed mainly by renewable resources. The variable and stochastic nature of some of these energy sources makes it necessary to have various tools to make the system flexible, including storage.

The National Integrated Energy and Climate Plan 2021-2030 (PNIEC) provides for the development of storage as one of the key tools for giving flexibility to the electricity system in order to support significant growth in renewable generation, as well as contributing to the management of the electricity networks, the participation of citizens in the change of the energy model and greater competition and integration in the electricity market. In order to develop the provisions of the PNIEC, this Strategy addresses the technical analysis of the different generation alternatives, the diagnosis of the current challenges of energy storage, the lines of action to advance in the fulfilment of the planned objectives and the opportunities that storage represents for the energy system and for the country.

There is a wide variety of storage technologies with different applications and characteristics that are complementary when it comes to giving flexibility to the energy system, either because of their application in the electricity sector and their relationship with the electrification of the economy, or because of their different end uses, such as thermal energy storage.

During the development of this Strategy, the first steps have already been taken to transform, in line with the European Directives, the regulatory framework that will need to be reformulated to integrate storage, both on a large scale and behind the counter. However, regulation will still need to be adapted to the new characteristics implicit in these technologies for the development of this new energy sector player. One of the key issues will also be determined by the opening up of storage participation to existing and future market mechanisms.

There are several opportunities in the development of storage along the entire value chain. The development of new business models is an opportunity in terms of employment, creation and strengthening of a national industry and reduction of dependence on critical materials from abroad. Maintaining existing national leadership is key, while opening up endless opportunities in the development of technologies that will be fundamental in the future. Taking advantage of this window of opportunity may mean obtaining technological and industrial leadership that will serve as a lever in the country's recovery.

New niche businesses linked to storage can be developed across all end-use sectors. There are applications for storage in mobility with the electric vehicle, which offers a range of new products and services; in the building sector through self-consumption of electricity and with thermal energy storage applications integrated into the building and its components; in the case of the industrial sector, which has a strong potential for self-consumption with storage, energy integration and decarbonisation of processes that use thermal energy, both cold and heat; as well as in other sectors, through self-consumption applications.

Research, development and innovation levers will be needed to, on the one hand, accelerate the technological development needed for the massive deployment of storage, and, on the other hand, to deepen technological leadership in low-carbon technologies.

The change of paradigm in the energy sector also implies giving a central role to citizens in the new design of the energy system. To this end, storage creates a favourable environment for citizen participation, the creation of quality employment and the improvement of the environment.

The deployment of storage technologies will be carried out with a comprehensive approach to sustainability, analysing their impacts throughout the life cycle of the technologies and minimising them.

The minimum storage needs for Spain, derived from the objectives of the PNIEC and the draft Long Term Decarbonisation Strategy (ELP) 2050 have been quantified in this strategy, going from the 8.3 GW available today to a value of around 20 GW in 2030 and 30 GW in 2050 of total storage capacity available in that year. This quantification includes daily and weekly large-scale storage, behind-the-meter storage and seasonal storage according to the current state of the art.

1. STRATEGY FRAMEWORK

The transformation of the energy system is one of the key factors in achieving climate neutrality by 2050. This change of paradigm requires a system based on renewable sources, which are stochastic and variable in nature. Therefore, the traditional vision of a centralized energy system based on manageable plants will be replaced by a decentralized and flexible system that allows for the adequate integration of energy provision through renewable technologies.

In this context of energy transition, storage is one of the challenges to be faced in the future to allow a full decarbonisation of the energy system and an effective integration of renewable technologies. The partial predictability of these technologies, as well as their variability, makes it necessary to have systems that address the existing instantaneous gaps in generation and demand, storing energy in periods of generation surpluses so that it is available when there are deficits.

This Strategy identifies the main challenges for the deployment of storage and a vision that represents a new paradigm for the energy system whose objective is climate neutrality and the exploitation of the opportunities that this change in model entails. The future supply of energy will come mainly from renewable sources, which in many cases are intermittent and unmanageable. The new needs for flexibility will therefore come from various areas. Energy storage will be one of the main elements providing flexibility to the energy system. This Strategy identifies the measures needed for an effective deployment of storage, so that this element is key to achieving climate neutrality.

1.1. International context

In recent years, different technological solutions have been developed to facilitate the integration of variable generation renewables, with diverse technical characteristics and which are capable of providing a varied range of services. According to data from the International Energy Agency (IEA), storage systems have considerably increased their installed capacity. The graph below shows the evolution of new installed capacity, which during 2019 increased capacity by 2.9 GW worldwide, including both large-scale storage and behind-the-meter storage. However, this growth has led to a reduction in the year-on-year increase of almost 30% compared to last year. Worldwide, storage amounts to about 160 GW, according to the IEA data.

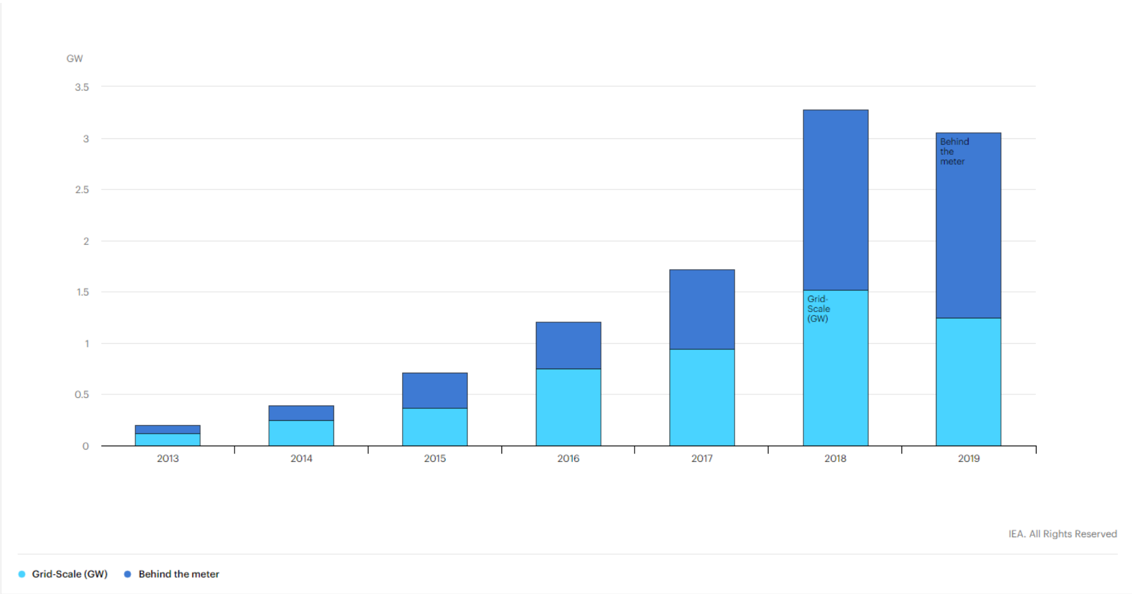


FIGURE 1. Annual evolution of new installed power worldwide. Source: IEA

The European Union's objective for 2050 is to achieve climate neutrality, which means assuming the commitment to increase global climate action in line with the **Paris Agreement**, adopted in December 2015 by the parties to the United Nations Framework Convention on Climate Change, and ratified by Spain in 2017.

The European Council conclusions of 12 December 2019 represent the formal agreement by the European Union to the adoption of the commitment to climate neutrality. This goal is embodied in the various scenarios included in the study carried out for the preparation of the Commission's Communication of November 2018, "**A Clean Planet for All. Europe's long-term strategic vision for a prosperous, modern, competitive and climate-neutral economy**". The various decarbonisation options included cover the need for energy storage in its various forms.

The **European Green Pact** launched in December 2019 presents a roadmap for achieving a sustainable economy in the European Union. Within the line "Supply of clean, affordable and secure energy", coinciding with the objective of sustainable development 7, of the Agenda 2030 approved by the United Nations, this framework involves accelerating the deployment of innovative technologies and infrastructures such as energy storage, including the necessary development of cutting-edge technologies in these key industrial sectors.

The recent agreement at European level on the **Recovery Plan** will give a boost to economic recovery after the crisis caused by the COVID-19 pandemic, through green investments, including storage technologies.

At the legislative level, the **"Clean Energy for All" package,**" includes various legislative provisions regulating energy storage in the EU: Directive 2019/944 concerning common rules for the internal market in electricity and Regulation 2019/943 on the internal market in electricity set out the principles for a new configuration of the electricity market that will encourage flexibility services and price signals suitable for the energy transition. Active customer, demand response and storage become key elements of the new regulatory framework. In Directive 2018/2001 on the promotion of the use of energy from renewable sources, reference is made to the use of energy storage in relation to energy from renewable sources.

In addition, there are various European initiatives aimed at the specific development of storage technologies, such as the launch in 2017 of the **European Alliance for Batteries**. This initiative aims to promote European leadership throughout the battery value chain, so that technological dependence is eliminated, while capitalising on European employment, growth and investment, creating a sustainable, innovative and competitive battery ecosystem. In 2019, the Commission's report on the implementation of the Strategic Battery Action Plan: Building a strategic value chain for batteries in Europe (COM(2019) 176 final) was presented.

Directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators is currently being revised to bring the environmental and end-of-life requirements of storage systems into line with potential growth and current penetration. One of the issues to be introduced by the reform will be precisely the possibility of new business models derived from the second life of batteries.

The **Hydrogen Initiative**, launched by the European Council of Energy Ministers in Linz in September 2018, endorsed by EU Member States and the European Commission, aims to focus on the potential of hydrogen for multi-sector decarbonisation, the energy system and long-term security of supply.

In March 2018, the Strategic Forum of **IPCEIs** (***Important Projects of Common European Interest)*** was created, as provided for in Article 107.3 of the Treaty on the Functioning of the European Union, as innovative projects that involve risks in their development and require joint work and investment at a transnational level. The objective of this figure is to encourage and facilitate the development of innovation projects, within the specific framework of state aid. In 2019, six new value chains were identified, including hydrogen technologies and systems.

In July 2020, **the European *Hydrogen Strategy*** was launched, which aims to develop clean hydrogen to contribute to decarbonisation, drawing up a roadmap for the deployment of hydrogen at EU level**.** This strategy was launched jointly with the **European Alliance for Clean Hydrogen**.

The **European Strategy for the Integration of the Energy System**, published by the Commission in July 2020, provides the necessary framework for the green transition, proposing a new integral vision in the planning of the energy system that takes into account the interrelations between the different energy carriers, with the objective of designing a decentralised, flexible and optimised energy system that exploits the many benefits of clean and innovative technologies. Systems to provide such flexibility include storage in its various forms, daily, weekly or seasonal.

1.2. National framework

The Strategic Energy and Climate Framework contains various strategic and legislative elements that aim to set out the main lines of action on the path to climate neutrality. It is composed of various documents:

- National Integrated Energy and Climate Plan (PNIEC) 2021-2030.
- Draft Long-Term Decarbonisation Strategy 2050.
- Climate Change and Energy Transition Bill
- Just Transition Strategy.
- National Strategy to Combat Energy Poverty

The **National Integrated Energy and Climate Plan 2021-2030** envisages achieving 42% renewable penetration in energy end-use by 2030, reaching 74% renewable in the electricity sector. To this end, it includes various storage technologies, to the value of 6 GW newly installed in that horizon. The model used for both the energy system and the analyses carried out for the peninsular electricity system considered 3.5 GW of seasonal storage, as well as 2.5 GW of large-scale daily storage. Other types of storage are also considered:

- Distributed storage, provided by the electric vehicle fleet *("Measure 3.10. The potential of the electric vehicle as an element* of *flexibility"*), as well as other ways of providing flexibility, such as demand management.
- Thermal storage, in particular coupled with solar thermal power plants.
- Chemical storage in the form of hydrogen.

The PNIEC, specifically in *"Measure 1.2. Demand management, storage and flexibility",* establishes some of the lines of action regarding regulatory changes to be implemented for the effective development of storage. This measure includes regulatory developments for both demand management and storage.

In addition to this measure, where storage plays a central role, storage deployment is present throughout the entire PNIEC. In *"Measure 1.3 Adaptation of electricity networks for the integration of renewables", the* role of storage in the integration of energy from renewable sources is considered. With regard to storage behind the meter and its deployment, *"Measure 1.4. Development of self-consumption with renewables and distributed generation",* addresses the deployment of self-consumption facilities, which in some cases will include storage systems.

From the point of view of energy system integration, in *"Measure 1.8. Promotion of renewable gases"* addresses the possibility of energy storage through transformation into renewable gases.

The inclusion of storage on non-peninsular territories as tractors is also envisaged in *"Measure 1.12. Singular projects and strategy for sustainable energy on the islands"*. Finally, in relation to citizen participation, future energy communities will be one of the elements of dynamisation of the energy system which will include the possibility of energy storage.

For its part, and based on the PNIEC, the draft **2050 Long Term Decarbonisation Strategy (LTS) outlines the** transformation path of the energy system for the years 2030 to 2050, tracing the evolution towards climate neutrality before that last year. One of the fundamental energy carriers for decarbonisation is green hydrogen, generated from renewable electricity, which is positioned as a key element for the integration of renewable resources in different sectors, including industry and transport, displacing the use of both industrial raw materials and fossil energy sources. The draft PLA includes the need for daily, weekly and seasonal storage for the period in question. Of particular relevance is the need for storage for the electricity sector, which will be 100% renewable by 2050.

For its part, the **Hydrogen Roadmap: a commitment to renewable hydrogen1 ,** approved by the Council of Ministers on 7 October 2020, recognises renewable hydrogen as a key tool for the integration of the different energy sectors, favouring energy security, availability and flexibility, as well as greater efficiency and profitability in the energy transition, contributing to the decarbonisation of the economy. Among the different roles to be assumed by this green hydrogen, the Roadmap highlights its relevance as a mechanism for seasonal energy storage, including among its measures actions aimed at promoting research for its progress.

The Hydrogen Road Map foresees the installation of 4GW of electrolyzer power by 2030, and a minimum contribution of 25% of renewable hydrogen to the total consumed by that year. In addition, it envisages a series of milestones on that horizon: a fleet of some 150-200 buses and 5,000-7,500 light and heavy vehicles powered by hydrogen, hydrogen trains on at least two non-electrified lines, at least 100-150 publicly accessible hydrogen generators for refuelling, and the introduction of handling machinery using renewable hydrogen fuel cells in the first five ports/airports in terms of volume of goods/passengers. In the long term, horizon 2050, this technology is expected to have reached a level of maturity sufficient to allow its large-scale deployment.

With regard to the regulatory framework, the **Climate Change and Energy Transition Bill** is the instrument that incorporates the energy and climate objectives for 2030 and 2050 with legal status and provides a stable institutional framework for this. The Bill includes some key provisions for the development of storage, having been the first legislative proposal to include some of the considerations of the Clean Energy Package for all Europeans in this area.

1 https://www.miteco.gob.es/images/es/hojarutadelhidrogeno_tcm30-513830.pdf

Royal Decree-Law 23/2020, of 23 June, which approves measures in the field of energy and other areas for economic recovery, already advances urgent measures with legal status which represent an important milestone in the introduction of storage in national regulation and in the development of new business models. The aforementioned provision includes the figures for storage and hybridisation in the Electricity Sector Act. In addition, the Law incorporates aggregation, together with the figure of an independent aggregator, and renewable energy communities. This last figure will facilitate, on the one hand, citizen participation in the energy system, while at the same time opening up the possibility of incorporating storage projects into distributed systems.

In addition, a special authorisation procedure is created for pilot and demonstration projects through the regulatory test beds, which can be applied for the implementation of tests for the future design of the storage regulatory framework. Finally, the Royal Decree-Law is a step towards the development of the ultra-fast recharging points required for the deployment of the electric vehicle in accordance with the objectives established in the PNIEC.

The strategic framework is completed with the **Just Transition Strategy,** which articulates the urgent support mechanisms for the regions and districts affected by the closure of thermal installations so as not to leave anyone behind, and in the development of which the inclusion of storage projects is foreseen as a driving force for activity and investment in these areas; and with the **National Strategy for the Fight against Energy Poverty**, which, although it does not foresee a specific development of storage, requires the development of a competitive and affordable energy system that guarantees the quality and accessibility of the energy supply. In this sense, there are also solutions such as the introduction of self-consumption systems that integrate storage equipment in buildings of vulnerable consumers, which would help reduce the bill, serving as an indirect structural measure against energy poverty.

For all the above reasons, the **main objective of the Energy Storage Strategy** is to ensure the effective deployment of storage as an enabler for the energy transition to climate neutrality, in accordance with the precepts established in the PNIEC 2021-2030 and in the draft ELP 2050. In a system with a 74% share of renewable energies in electricity generation by 2030 and 100% by 2050, flexibility will be essential to be able to operate safely. In this sense, it is essential to carry out an effective design of market mechanisms to provide the necessary flexibility to the system. These mechanisms will not be exclusively oriented towards the contribution of electricity generators. In addition, participation will be open to all forms of flexibility and distributed storage, with the emphasis on involving demand, in particular citizens, in the design of these mechanisms.

Therefore, in order to provide the flexibility needs of the energy system, different solutions will be necessary from the supply and demand side. Among these, a wide range of storage solutions must be available, with different technologies and performance, and various locations in the energy system, both in front of and behind the meter.

The technological evolution, which at this point introduces a degree of uncertainty in the design of future systems, will mark the consolidation of the different alternatives for energy storage. Due to the different energy applications, electrical end uses or thermal energy, the temporal characteristics of storage, as well as other technical or environmental parameters, storage technologies provide different performances that are not exclusive but complementary.

Currently, the Self-Consumption Strategy, the Biogas Roadmap, and the Roadmap for the Development of Offshore Wind and Marine Energy in Spain are also being prepared. All of them are complementary to this Strategy, either because of their relationship with the integration of the energy system, or because of their role in the deployment of storage behind the meter.

2. ENERGY STORAGE SYSTEMS

In general terms, energy storage is the set of methods, systems and technologies that allow energy to be transformed and conserved for later use. Energy storage is currently based on a wide range of technologies, many of which already have a long history and a solid state of maturity, while others are less consolidated and require progress in certain aspects and improvements in performance, cost and competitiveness. In general, this spectrum of technologies, described below, can be classified according to the following table:

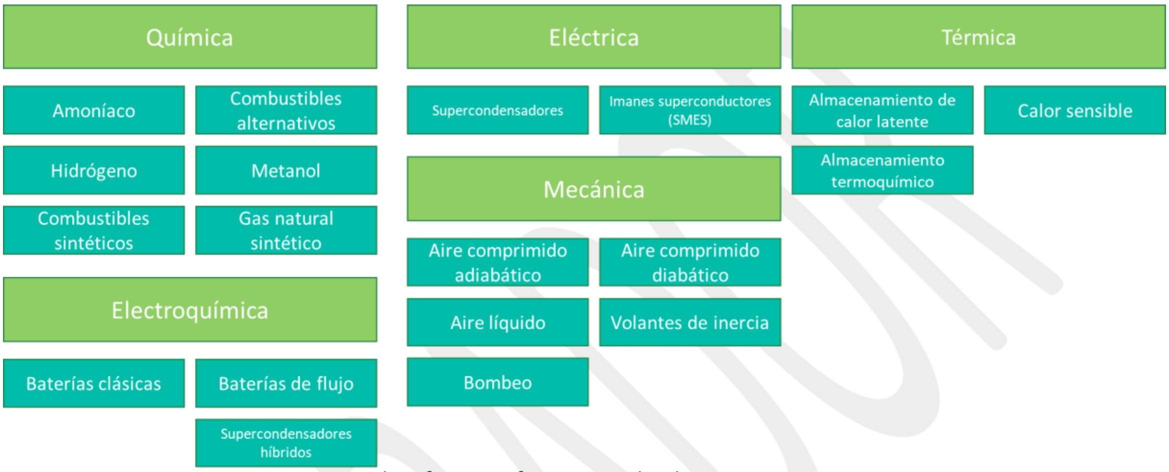


FIGURE 2. Classification of storage technologies

2.1. Mechanical systems

2.1.1. Hydraulic pumping stations

Pumping plants store energy in the form of the gravitational potential energy of water, raising water from a lower reservoir to a higher one. During periods of high demand, the water stored in the upper reservoir is released by turbines into a lower reservoir to produce electricity, while in periods of low demand the water is pumped back into the upper reservoir and stored again. Although these are generally surface reserves (reservoirs, deposits, etc.), the sea or underground caves can also be used as a lower reserve.

Pumped energy storage is one of the most mature storage technologies and, thanks to its efficiency and flexibility, it is implemented on a large scale throughout Europe. It currently accounts for more than 90% of installed storage capacity in Europe.

Pumping plants require very specific site conditions in order to be viable, such as proper ground shaping, the difference in elevation between the reservoirs and the availability of water for operation. In addition, the civil works they require may have a high environmental impact. For this reason, there is a great potential for reusing hydroelectric installations, by adding systems pumping stations and there is also the possibility of extending existing pumping stations by adding new units with the same hydraulic infrastructure of reservoirs or deposits.

Another option proposed as a lever for generating employment in the rural environment and rehabilitating the natural space affected by mining operations is the use of water from mine drainage for the production of electricity by means of a reversible treatment plant. This involves the use of water from mines abandoned over the years which, as it is leachate from the mines themselves, is a pollutant, which would also solve the environmental problem posed by these discharges into the various water basins. They have in common the use of open skies and dumps as storage ponds within the mines, specifically as lower and upper accumulation tanks. Therefore, this technology would present additional benefits as it is located in areas of Just Transition and near closed thermal power stations or in the process of being closed.

One of the innovative pumping projects is seawater pumping, in which one of the tanks is precisely the sea. There are projects in which the water used requires a desalination process, while in other unique projects, seawater is used directly.

2.1.2. Diabetic and adiabatic compressed air

Also known as CAES (*Compressed Air Energy Storage*), this is a system in which electrical energy is stored in the form of high-pressure compressed air and extracted by expanding it through turbines, providing heat to the air. To store the air, suitable geological locations or suitable tanks are required. Storage using compressed air will be either diabolic or adiabatic depending on whether or not heat is transferred with the environment, with performance generally being higher in adiabatic systems. In the latter systems, the heat previously captured in other phases of the process is used.

In general, a compressed air installation integrates various components, devices and processes. Common to all of them are compressors, expanders and air storage tanks. The rest of the components vary according to the structure and the operation principles of the system.

2.1.3. Liquid Air

Also known as LAES (*Liquid Air Energy Storage),* this system uses liquid air as an energy carrier and can be integrated into industrial heat and cold processes. The process is carried out in an industrial air liquefaction plant that uses electrical energy to cool the ambient air, until liquid air (cryogenic) is produced and stored in an insulated tank at low pressure. When energy is required, the liquid air is pressurised, regasified and expanded in a turbine to generate electricity.

This storage can be accompanied by two thermal storage systems associated with each of the air compression and expansion processes (cold and hot focus). The implementation of these systems allows to increase the efficiency of the conversion.

2.1.4. Flywheels

Flywheels are mechanical devices capable of storing kinetic energy by means of a mechanically rotating inertia disc coupled to an electrical machine operating either as a motor or a generator, controlled by power electronics, and connected accordingly either to the mains or to the load. During charging, the electrical machine operates as a motor: the energy provided by the mains causes the flywheel rotor to move until it reaches its nominal speed, thus storing a certain amount of kinetic energy. During discharge, the electrical machine operates as a generator, transforming the stored mechanical energy into electrical energy which is returned to the grid and slowing down the device to its minimum design speed.

This technology enjoys a high penetration in the industrial market due to its high dynamic response capacity, power and energy density, as well as the opportunities it provides to decouple power and energy in the design range, with a high number of life cycles and ease of installation.

2.2. Electrochemical systems

Electrochemical energy storage converts electrical energy into chemical energy to be stored, usually through the use of electrochemical batteries or capacitors. Batteries are composed of cells, which store energy through oxidation and reduction processes.

Although there are different types of batteries, described below, this is a mature system in general, very useful as a short-term storage system requiring frequent charging and discharging. Its value chain is complex and requires the collaboration of the suppliers of the raw material and of the critical and advanced materials, the cell manufacturers, the suppliers of the battery pack and the integrators in the storage networks of their facilities.

The main short and medium-term objectives of most technologies within electrochemical storage are to reduce costs and increase the life span of the systems.

2.2.1. Conventional batteries

Classical electrochemical batteries contain two or more electrochemical cells that use chemical reactions to create a flow of electrons in an external circuit, i.e. electric current. The primary cell elements include a container, two electrodes (anode and cathode), a liquid or solid electrolyte material and a permeable membrane that allows ionic flow between the electrodes while preventing short circuits between them. The electrolyte is in contact with the electrodes, so that the current is generated by the reactions of oxidation and reduction between the electrolyte and the cell electrodes When the battery is connected to a charge, the electrolyte near one of the electrodes causes the release of electrons (oxidation) by dissolving the electrode material. Meanwhile the ions near the other electrode accept the electrons (reduction) and complete the process of discharge. By reversing this process the battery will be charged.

Their composition in cells gives them a highly modular character and suitable for their manufacture, being able to be combined in series until reaching very high tensions and in parallel to obtain the necessary power. It is advisable to avoid high currents and low temperatures in order to avoid degradation due to undesired chemical reactions.

Classic batteries have very attractive power densities and their cycle efficiency is in the range of 60-70% depending on the charging and discharging conditions, which is why this technology is already widely used worldwide and connected to the grid. With a wide variety of possible materials (lithium based, high temperature or sodium based, lead nickel, metal air, or nickel) its future growth prospects are very promising.

2.2.2. Flow batteries

Redox flow batteries use two reagents which, on contact, are transformed into another compound, producing electrical energy. In this case they use two electrolytes (liquid or combination of liquid and gas), one in a high state of oxidation and the other in a low state of oxidation, so that they act as energy carriers. The electrolytes are divided by means of a separator, generally an ion-selective membrane, which in charge and discharge conditions allows certain selected ions to pass through it and complete the chemical reactions at cell level.

This technology presents a wide variety of electrolyte combinations, some of which are still under investigation. Commercially, Vanadium batteries (VRB) stand out, with a very fast charge/discharge response, with a much higher number of charge/discharge cycles than other types of batteries and usually used for power quality and voltage voids, and Zinc-Bromo (Zn-Br) batteries.

Thanks to its modularity, the power (kW) and capacity (kWh) configurations are decoupled. Specifically, the power of the battery is determined by the total surface area of the membrane, while the capacity depends on the volumes of active material. Their level of maturity is lower than that of classic batteries.

2.2.3 Hybrid Supercapacitors

Supercapacitors store the electrical charge in a double electrical layer at the interface between a carbon electrode and an electrolyte liquid. This is a highly reversible mechanism, as is the case with conventional capacitors, allowing them to be charged and discharged at high power ratios. In comparison with batteries, their energy density is lower, while their specific power is higher. Their performance would be multiplied if they were combined with lithium ion batteries.

Still in the early stages of research and development, and in some cases of prototype demonstration, this system combines the virtues of both technologies and has a high potential.

2.3. Chemical systems

Chemical storage systems are based on the transformation of electrical energy into energy from chemical bonds of certain molecules, to be extracted when required, or to use these molecules in industrial processes.

These systems allow for an exchange of energy between the different energy sectors, establishing transversal connections between the electricity sector and the gas, petrochemical and chemical sectors. The name *Power-to-X* (P2X) groups together a range of generic technologies that convert electricity into various energy carriers, with the possibility of combining it with CO_2 to be synthesised into energy-rich gases and liquids (*Power-to- Gas* and *Power-to-Liquid*) that can be used as fuels or combined with nitrogen *to* generate chemicals such as ammonia. By using fully renewable electricity, renewable fuels will be achieved.

The chemical storage systems detailed below are described in greater depth in the aforementioned Hydrogen Roadmap: a commitment to renewable hydrogen2 , aimed at identifying the challenges and opportunities for the full development of renewable hydrogen in Spain. This Road Map seeks to contribute to the reduction of local polluting emissions and greenhouse gases generated during the production cycle, while taking advantage of renewable energy for direct use, or surplus energy generated during the hours of least electricity consumption, allowing for manageability and continuity in the renewable supply through its energy storage capacity.

2.3.1 Hydrogen

Hydrogen is not a primary energy source but an energy carrier, i.e. a product that requires an energy input to be obtained and which is capable of storing energy in its bonds that can then be gradually released when required. Its energy density is lower than that of other fuels.

Hydrogen is commonly classified as green, grey or blue depending on its origin. Grey hydrogen requires natural gas or other light gases for its production, while blue hydrogen is produced from natural gas with CO2 capture and storage systems. Green hydrogen can be obtained through electrolysis, consuming electricity from renewable energies. The process consists of dissociating the water molecule into oxygen and hydrogen in a gaseous state by means of a continuous electrical current. There are various types of electrolysers depending on the technology used, the most common being currently alkaline and PEM (*Proton Exchange Membrane)* type, used in most applications. Likewise, the solid oxide electrolyzers (SOEC), still under development, stand out for their efficiency and capacity to convert the hydrogen generated into electricity

[2] https://www.miteco.gob.es/images/es/hojarutadelhidrogeno_tcm30-513830.pdf

again through the use of reversible devices. Additionally, hydrogen can be obtained by other methods, such as photocatalysis or thermolysis, at a still low state of technological maturity.

Due to its condition as an energy vector, hydrogen provides a wide range of options for its application in end uses, especially in mobility, through the use of fuel cells, and within industry, both for its use as a raw material in the refining and chemical industries, and for its energy application in the metallurgical industry. With regard to its energy applications, hydrogen has an important future potential for medium and high temperature heat processes.

2.3.2 Ammonia, Methanol and Alternative Fuels

To increase the volumetric energy density and to take advantage of other existing infrastructures, hydrogen can be incorporated into larger molecules such as ammonia or organic hydrogen-carrying liquids. Thus, hydrogen can give rise through synthesis to liquid substances that are easily transportable using existing supply networks, such as methanol, octane, ammonia or ammonium derivatives. Among these, ammonia stands out, as it has its own developed infrastructure that would favour its storage. This compound does not contain carbon in its molecule, although it does have nitrogen and its emissions contribute to the formation of ammonium sulphate and ammonium nitrate aerosols, which deteriorate air quality.

2.3.3 Synthetic fuels

Hydrogen, combined with carbon monoxide (synthesis gas) can be used to produce fuels with properties similar to fossil fuels. From the synthesis gas (hydrogen and carbon monoxide), through a Fischer-Tropsch process, it is possible to synthesize hydrocarbons, obtaining synthetic liquid fuels of renewable origin such as dimethyl ether (DME), diesel or synthetic paraffin. These fuels of non-fossil origin not only allow large-scale and long-term energy storage, similar to the storage of fossil fuels, but also contribute to the carbon neutrality of the fuel, which is essential for the decarbonisation of the transport sector. From hydrogen, synthetic methane can also be obtained with CO_2 or biomass. This option also allows the use of gas network infrastructure for storage and transport.

2.4. Thermal energy storage systems

Thermal energy storage, in the form of heat or cold, is a cross-cutting technology that contributes to the future energy system in various ways: it increases the percentage of renewable and low-carbon energy, taking advantage of electrical energy discharges to produce heat or cold for later use; it presents a great potential for hybridisation with other energy technologies; it adds flexibility to the operation of energy plants and industrial processes; it favours the recovery of residual heat from industrial processes; and it improves energy efficiency in industrial processes and buildings. Additionally, in many areas and applications the use of thermal energy is necessary, such as for example in heating and/or cooling systems for industrial use or for air-conditioning. In this sense, the combination with other technologies, such as heat pumps with storage tanks, either in the form of hot water storage (sensible heat) or with phase change tanks (latent heat), allows the integration of electricity and thermal energy at various scales.

2.4.1 Sensitive heat storage

It is the most widely used thermal storage technology in residential and industrial scale applications. Its operation is based on increasing or decreasing the temperature of a liquid or solid material with a high calorific capacity (oils, water or molten salts) with the aim of storing and releasing thermal energy for low temperature applications.

For low temperatures (up to 120°C), water is used as an effective and very low-cost means, usually in small, well-insulated tanks, which, due to their temperature range, allow the use of solar thermal energy. If higher volumes are required, a wide range of underground storage facilities are used (caves, wells, even hybrid versions combining several solutions). In the residential area, it is very common to use the domestic hot water thermostat (DHW). These devices, integrated in self-consumption systems, make it possible to take advantage of surplus renewable generation. Furthermore, in the event of adding intelligent control systems, these devices can be managed in an aggregate manner to provide flexible services to the network.

For high temperatures, the most common fluid is molten salt because of its excellent ratio between storage capacity and cost. In addition, high operating temperatures are compatible with applications such as value cycles, which allow electricity to be returned to the grid.

Additionally, there are storage solutions in solid materials, in which heat is transferred directly from a gaseous medium to materials such as ceramic bricks or natural stones, such as volcanic ones.

2.4.2 Latent heat storage

Latent heat storage *materials,* or PCMs, transfer the energy absorbed or released during their phase *change,* which occurs at a constant temperature, and have a higher energy density than sensible heat technology.

Materials are selected according to the temperature range required: watery salt solutions or ice if the temperature is below 0ºC, being already present on a large scale; fatty acids, salt hydrates or alcohols if the temperature is between 90 and 200ºC; and metals and carbonates from 400ºC.

2.4.3 Thermochemical heat storage

These systems use thermal energy to dissociate the compounds into two reactive products that store heat separately. A subsequent recombination of the

Reactants generate an exothermic reaction that releases the stored heat. The reactions can be gas-gas or gas-solid. The latter take place at a constant temperature, which allows the selection of tailor-made reactants for each specific application as well as decoupling power and capacity.

They can operate through reversible chemical reactions, through processes of absorption and dissolution of a material, or through adsorption reactions, in which the reactants are separated during the energy charge and the heat of the reaction is released after recombination.

Despite their potential, these systems, in general, are not yet a mature alternative on a large scale in the market, with the exception of some applications such as ammonia-water or lithium bromide absorption machines which are somewhat established in the industrial sector. It is still necessary to improve certain aspects such as the properties of the materials to achieve greater stability of the system, as well as in relation to its cost.

2.5. Electrical systems

2.5.1 Supercapacitors

Supercapacitors are passive electronic components that allow energy storage in short periods of time thanks to the accumulation of electrical charge in a double electrical layer at the interface between a carbon electrode and an electrolyte liquid. It is a highly reversible mechanism, as it happens with conventional capacitors, which allows their charge and discharge at high power ratios. The distribution and size of the pores and the surface area of the electrode determine the storage capacity of these devices, which is much higher than that of conventional capacitors. Their energy density is lower than that of batteries, while their specific power is higher, so their performance is multiplied when combined with lithium-ion batteries. Current research is aimed at increasing the capacity of the electrolytes while mitigating their toxicity.

2.5.2 Superconducting magnets (SMES)

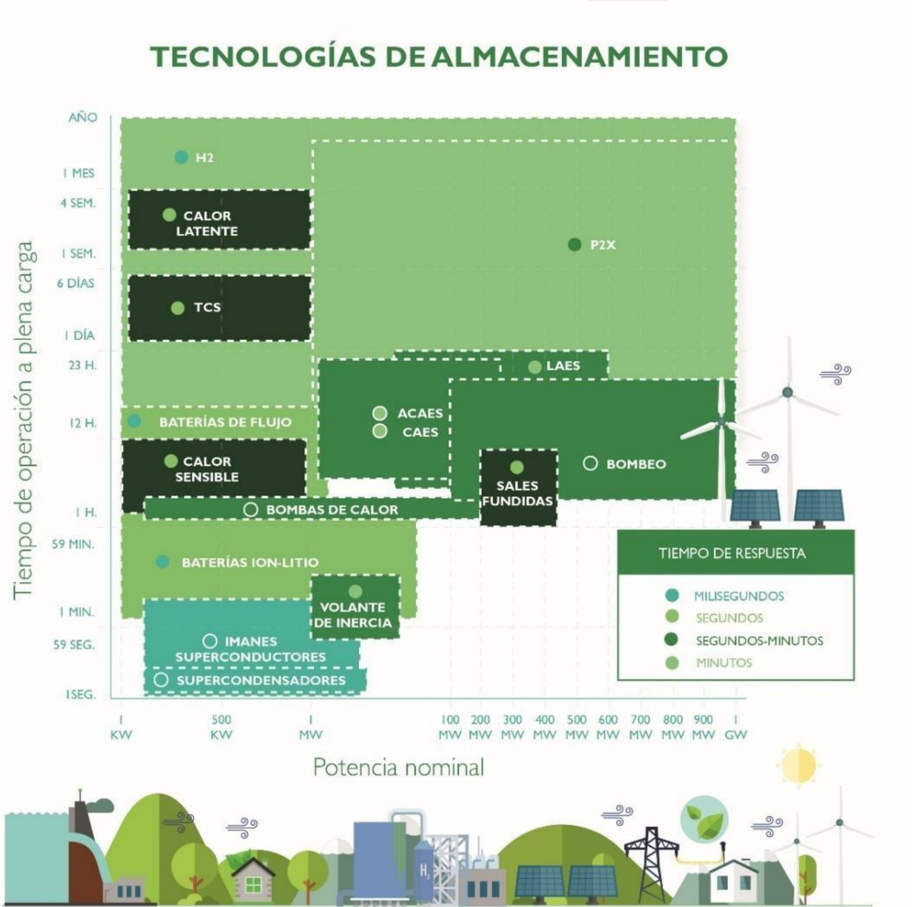
Superconductors store energy in magnetic fields generated by an electric current in superconducting coils. These systems require cryogenic temperatures for their operation, allowing energy storage with minimum electrical losses due to the negligible resistance of the material, as well as a fast and very efficient delivery of high powers.

The basic elements of the SMES are: a superconducting coil, a cryogenic system, a coil control electronic system and the power electronics to store the energy from the network and return it.

The combination of superconductors with batteries can provide systems with high energy and power densities, full charge and discharge capabilities and an extended lifetime with virtually no limitation on the number of cycles. Its main drawback, the high cost of cryogenic infrastructure, is being mitigated by improving the range of operating temperatures. Current research is oriented towards a hybrid system combining SMES with liquefied hydrogen (LIQHYSMES) or with CAES systems.

2.6. Characterization of the different technologies

The performance offered by different storage technologies varies according to characteristics such as their nominal power or response time. The graph below shows the different technologies described in the previous sections, according to these parameters, with a table showing the typical ranges of other relevant characteristics, such as capacity, efficiency or level of maturity.



TECNOLOGÍA		CAPACIDAD ENERGÉTICA	EFICIENCIA DE CICLO COMPLETO	NIVEL DE MADUREZ
MECÁNICA	Bombeo (PHS)	1-100 GWh	80%	
	Bombas de calor (PHES)	500 k Wh - 1GWh	70 - 75%	
	Aire comprimido adiábatico (ACAES)	10 MWh - 10 GWh	> 70%	
	Aire comprimido (CAES)	10 MWh - 10 GWh	45 - 60%	
	Aire líquido (LAES)	10 MWh - 8 GWh	50 - 100%	
	Volante de incercia	5 - 10 kWh	85%	
ELECTROQUÍMICA	Baterías ión-litio	<10 MWh	86%	
	Baterías de flujo (V, Zn,Fe, Zn Br)	<100 MWh	70%	
ELÉCTRICA	Imanes superconductores (SMES)	1 - 10 kWh	>90%	
	Supercondensadores	1 - 5 kWh	90%	
QUÍMICA	Power to gas (H2)	Hasta 100 GWh	20- 40%	
	Power to X (P2X)	1 MWh - varios GWh	50%	
TÉRMICA	Sales fundidas	3 GWh	40%	
	Calor sensible	10 - 50 kWht	50 - 90%	
	Calor latente (PCM)	50 - 150 kWht	75 - 90%	
	Termoquímico (TCS)	12 - 250 kWht	75 - 100%	

MUY MADURO NO MADURO

FIGURE 3: Operating parameters of storage technologies

2.7. Storage for energy transition

Depending on the different technical characteristics, performance, discharge time or end-use applications of the energy, the wide range of existing storage technologies can contribute in a combined way to provide the flexibility that the system requires for its gradual decarbonisation, until climate neutrality is achieved. Depending on the different types of storage described above, energy storage has various applications, and consequently has the capacity to provide a wide range of services aimed at various end uses. Some of these can be seen in the following figure:

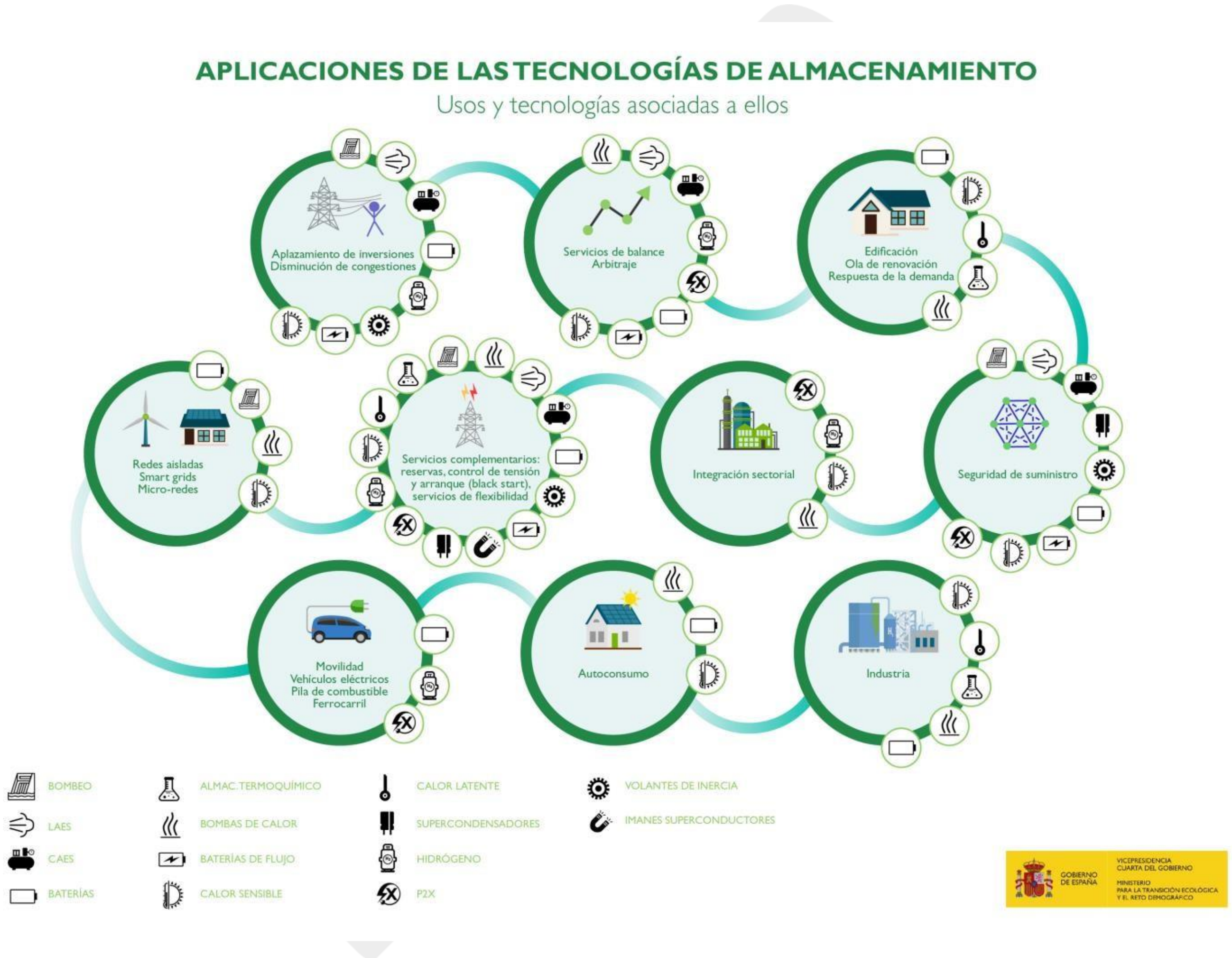


FIGURE 4. Applications of storage technologies

Depending on the different applications, there will be storage systems with different sizes, either large-scale storage, or "*in-front of the meter", or* small-scale storage or distributed systems, called "*behind the meter*".

Specifically, in the electricity sector, the presence of storage will be increasing in the short and medium term, mainly due to the growing presence of renewable energy sources. Specifically in this sector, the services in which storage systems could potentially participate can be summarised in the following figure:

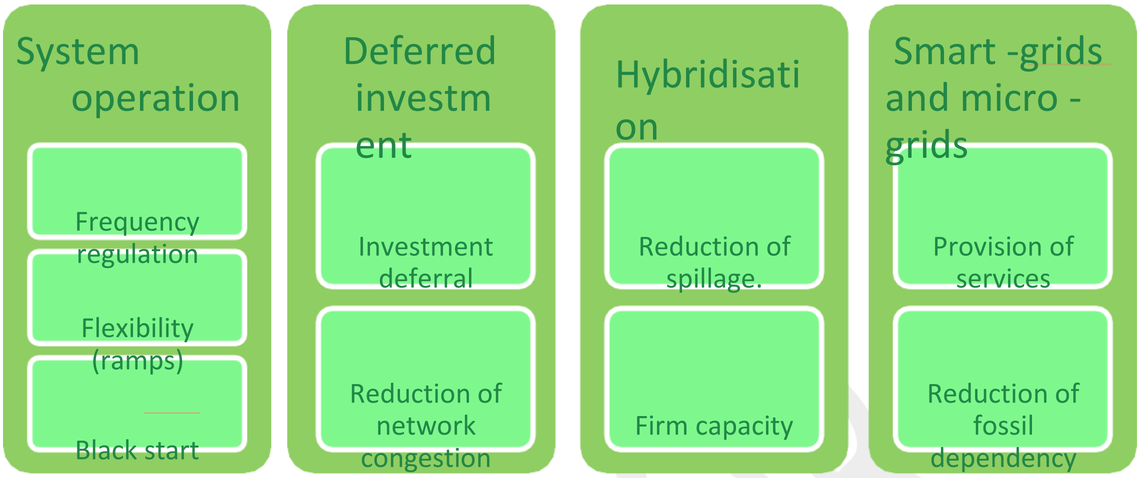


FIGURE 5. Main services from storage to the electricity system

3. THE ENERGY STORAGE VALUE CHAIN

The energy storage value chain is made up of several phases, all of which have a great deal of room for promoting national industry, opening up the opportunity to strengthen its leadership on an international level. In this sense, it is essential to have national manufacturers and suppliers who generate high added value and drive innovation and competitiveness in the sector, from the supply of raw materials and basic components, through the manufacture and development of technologies, to the provision of all types of services through the new business models associated with storage.

On the other hand, the circular economy has achieved that the industrial value chains go from a linear character, based on the extraction, transformation, use and waste of the systems, to a circular model in which reuse and recycling play a very relevant role, reducing to the maximum the inputs and outputs of elements within this chain and closing the life cycle of the products.

In general terms, the value chain of the energy storage industry consists of the following phases or links:

Supply of materials and components

This phase includes suppliers of raw materials and manufacturers of electronic parts and components required for the production of the storage systems. In line with the circular economy, many of these components and raw materials will, where appropriate, come from other systems that have reached the end of their useful life. The detail of the industries integrated at this stage of the chain varies with the storage technology. In the case of electrochemical storage using batteries, for example, it is broken down into the extraction of raw materials and/or the recovery of materials from disused systems, the obtaining of active materials and the manufacture of cells for subsequent use in the production of batteries.

Production of storage systems

This stage involves the manufacture of the different storage devices, depending on the technology, by assembling the different components, constituting the main and auxiliary systems. Taking the example of battery manufacturing, this phase would include the production of battery modules and packs from the cells, as well as the associated management systems.

Integration and development

The devices manufactured in the previous phase are equipped with the necessary electronic components to meet the requirements of their final application, as well as the development of integrated solutions and applications for the operation and management of storage systems in all their sectoral applications.

Services to the end user

This phase integrates the providers of the different services related to energy storage and management, ranging from system installers to the operation and maintenance of the systems, as well as the consumers themselves, who are taking an increasingly active role at this stage, getting directly involved in various tasks related to it. The spectrum of applications is very wide and the type of service varies with the technology and end use, ranging from large-scale storage system integration to provide flexible services to the transmission network, hybrid systems with renewable generation plants, systems integrated into distribution networks to systems for use in self-consumption facilities, intelligent networks or mobility, among others. This stage also includes a multitude of new business models, such as independent aggregators or renewable energy communities, which in turn allow consumers to play an active role, participating directly in the management of their energy.

Waste management and recovery, recycling and second life

This stage closes the life cycle of the storage systems. Each component, depending on its characteristics, will follow a different management path. The current model, based on the circular economy, prioritises their reuse if it is viable. If this is not the case, the aim is to recycle or, where appropriate, to manage as waste with no intended use, in all cases maximising the reusable resources from this waste. Again using the example of batteries, there is great potential in the development of business models related to the second life of these systems.

On a large scale, the reuse model can be transferred to large disused facilities, to be transformed into energy storage infrastructure. In this sense, there is great potential for the reconversion of, for example, old fossil fuel-based generation plants, which have ceased to operate to make way for cleaner technologies and which can be reused, at least partially, taking advantage of the opportunities of the energy transition and bringing their benefits closer to the regions where they are located.

Cross-cutting aspects in the value chain

In addition, the value chain is made up of other activities of a transversal nature. Firstly, activities related to research and technological development, innovation and competitiveness take on special relevance throughout all the stages, as well as in the processes that make them up, as essential tools for achieving the best technological solutions at all levels.

For their part, in an increasingly integrated and interconnected sector, standardisation and interoperability play a fundamental role and must be considered throughout the chain. In this respect, the penetration of intelligent networks and technologies and the associated handling and mass transmission of data give a leading role to the cybersecurity, which is necessary to ensure the integrity of infrastructures and the protection of data and users.

There is also a business opportunity in the search for standardisation solutions for the different areas of the value chain. One of the windows that are opening is in the new business models, such as the definition of standards in the second life of batteries.

In short, an exhaustive analysis of the value chain of energy storage systems reveals the variety of activities that make it up, which translates into multiple opportunities for the development of new business models and for the promotion of a competitive, innovative national industry that provides high added value in all its links and achieves a leading international position in the sector.

FIGURE 6. The energy storage value chain

4. ENERGY STORAGE DIAGNOSIS: CHALLENGES

The challenges facing storage have been studied for years by the European Commission3 (EC), in studies where a series of problems with existing policies and the resulting barriers in various areas were identified, such as the design of energy markets, ancillary services and capacity mechanisms, as well as specific storage practices, such as network tolls. More recently, in March 2020, the EC has published a study which examines in depth the challenges and opportunities of storage systems. This study compiles data on different energy storage policies in EU Member States.

Based on these previous studies, the knowledge of the specific casuistry (regulatory, market, etc.) of the Spanish case, and the information collected in the framework of the elaboration of this Strategy, the main challenges are classified in the following nine groups:

- Regulatory and market.
- Economic and business model-related.
- Concerning standardisation and the need for interoperability standards.
- Cybersecurity.
- Sectoral integration.
- Research and development of storage technologies.
- Of behaviour, lack of information or risk aversion.
- Social and environmental.
- Critical materials.

[3] *The* European Commission working document *"The future role and challenges of Energy Storage" from* 2013, the white paper *"Energy Storage: the role of electricity" from* 2017, related to the Clean Energy Package and the design of a new electricity market.

[4] *"Study on energy storage - Contribution to the security of the electricity supply in Europe"*

FIGURE 7. Storage challenges

4.1. Regulatory and market challenges

In the context of an electricity market and its regulation originally designed for mainly conventional, manageable, centralised thermal generation without large storage needs, there is a certain inherent difficulty for storage facilities in participating in electricity markets, which could hinder their profitability. In general, change processes which require adaptation of regulatory frameworks generate uncertainty, making planning difficult and damaging the financial expectations of investors. Therefore, ensuring a level playing field for all users and applications and increasing investor security is crucial to facilitate investments and achieve a competitive energy system, especially as European regulations call for an opening of all markets to resources such as storage or demand management.

This group of challenges is discussed in more detail below.

Adaptation of current legislation to storage

A first, very important step was taken with Royal Decree-Law 23/2020, which approved measures in the field of energy and other areas for economic recovery, where for the first time a definition of the "owner of the storage facility" as a subject in itself was introduced into the Electricity Sector Act, while recognising that other agents, such as producers, consumers or owners of electricity networks, may also use storage facilities. On the basis of this definition, it is also necessary to define additional aspects such as their rights and obligations and the role to be played by distributors and the system operator, taking into account the limitations set out in Directive (EU) 2019/944 on common rules for the internal market in electricity. The Royal Decree-Law also includes the figure of the "independent aggregator" in the Electricity Sector Act, with a wording based on that of Directive (EU) 2019/944.

In addition, it is necessary to define the process to be followed when processing the corresponding permits for the storage systems, and a system to provide visibility to the storage facilities being developed. Therefore, the process for applying for access and connection of storage facilities, whether new or existing plants incorporating a storage system, must be specified, as well as the other procedures to which they must be subject, where applicable. The next Royal Decree on access and connection, which is already at a very advanced stage of processing, will regulate access for storage facilities that inject energy into the network.

Market access for storage technologies

Currently, storage has no defined mechanisms to participate in the energy and ancillary services markets, with some exceptions for pumped storage and thermal storage associated with solar thermal plants.

In Spain, following the CNMC's resolution of 11 December 2019 approving the conditions relating to the balance sheet for suppliers of balance sheet services and settlement agents responsible for the balance sheet in the Spanish peninsular electricity system, the door is now open to the possibility of storage participating in balance sheet services. In line with this provision, the operating procedures drawn up by the System Operator are being modified to allow storage to participate. The proposed amendment has already been subject to public consultation, including provisions on storage.

Currently, the Order creating the strategic reserve for rapid response to support the access services of the electricity system is being processed, which includes the participation of energy storage facilities, assuming the participation of these facilities in this new modality of adjustment services.

On the other hand, storage can provide other services such as voltage control and start-up (*black start*). However, at present, its participation in services is not regulated adjustment measures such as technical restrictions, reducing the options available in terms of markets for storage.

Finally, it will also be necessary to develop how storage (and other distributed resources) could provide remunerated flexibility services to distribution network operators (as set out in Article 32 of Directive (EU) 2019/944).

Market structure and price signals

Moving forward in the evolution of market structure, the development and integration of local electricity markets is a challenge and a necessity in the process of energy transition, where storage can play a key role. These markets for renewable production facilities and consumption in distribution networks (consumption management, production facilities in buildings, batteries, electric vehicle charge management, etc.) allow users to benefit from better market prices due to their flexibility and management, favouring the integration of renewable energies and consumer empowerment.

The very design of the market affects the profitability of these installations. Market signals must be appropriate to provide incentives to build storage capacity and provide storage services. A significant difference between areas such as California, Italy and Spain is the model of market design and the geographical resolution of price signals. Unlike Spain, which applies a single price area model, California has a marginal location in a system with prices at a nodal resolution. On the other hand, Italy would be an intermediate case, as it has several bidding areas. In principle, incentives for energy storage systems are higher the more granular they are. This is due to a higher volatility compared to an "average" price if a supply area is large. This is an area where the development of regulatory demonstration projects could make particular sense.

Tolls, taxes and charges

CNMC Circular 3/2020 already exempts batteries connected to the transmission and distribution network from grid connection tolls, but according to the European study (mentioned above) double taxation persists at European level, with taxes being levied on both absorbed and injected electricity.

The draft Royal Decree establishing the methodology for calculating electricity system charges excludes storage systems and pumping from the payment of charges.

For chemical storage alternatives, such as hydrogen from electrolysis, the cost of electricity is one of the main components of the cost of the final product. In this respect, further analysis is needed on the optimal treatment in terms of tolls and charges of storage systems where electricity is consumed but subsequently no electricity is fed into the grid (e.g. when the final product is destined for industrial uses) with respect to storage systems where electricity is consumed and fed into the grid.

Coordination of European storage regulations

At European level, the "Clean Energy for All Europeans" legislative package is an important step towards boosting storage. However, in order to effectively support the deployment of these technologies, it is also necessary to adapt the other applicable legislation. For example, the current guidelines on state aid for the environment and energy do not cover storage, so in the review being carried out by the European Commission, it may be necessary to expressly include storage technologies as systems exempt from notification (at least under certain conditions).

4.2. Economic and business model challenges

The most important barrier to the development of storage is the shortage of references from viable commercial cases. In order to make investment in storage feasible and thus to meet the objectives set, it is desirable that the various markets properly assess the contribution and services it can provide and that the regulatory framework favours its deployment. In the short term, several barriers still hinder the development of energy storage in the EU and create uncertainty about revenue flows to cover project costs and risks.

Some of these challenges are described in more detail below.

Achieving profitability under current market conditions

Certain technologies are not yet profitable for certain consumer profiles. This is the case with some of the installations *behind the* meter (such as batteries), which will need to be encouraged in the development of business models that facilitate their penetration (pilot programmes, aid programmes, etc.), associated with energy communities, with hybridisation of technologies (for example, photovoltaic with batteries), etc. As an example, there are various references at a European level of *virtual power plants (*a group of distributed generating installations which allow storage systems to participate in different markets or fulfil various functions simultaneously, controlled collectively) which show that this could be a business model to explore, for which we will analyse whether changes are required to the current regulatory framework.

The following uncertainties strongly affect the economic evaluation of energy storage:

- The existence or not of storage compensation schemes.
- The potential to develop new and innovative business models, and the emergence of new players, such as independent aggregators. Several of the energy storage studies mentioned show that the provision of a single service (e.g. price arbitrage) is not sufficient to make the storage scheme profitable; other paid services (e.g. frequency, voltage) are needed.

The need for industrial policies to provide incentives for financing storage systems

Measures are needed to encourage the development of the industrial value chain and investment in such systems in the marketplace, until storage systems are economically profitable and mature.

Support systems for medium to large sized installations such as the implementation of auctions for manageable technologies, as described in the draft royal decree regulating the economic regime for renewable energies for electricity production installations, could be a way of incentivising their development in a cost-efficient manner. A list of the various sources of financing for storage systems is included in the annex to this strategy.

4.3. Standardisation challenges and the need for interoperability standards

New business models will be developed thanks to the intensive use of information and communication technologies, allowing, among other aspects, the aggregation of distributed resources such as storage, demand management and the electric vehicle. Specifically, the electric vehicle could be used to supply energy to users in their homes in periods of shortage (V2H, Vehicle to *Home),* as well as to store it and provide auxiliary services to the system, by means of vehicle to grid applications (V2G, *Vehicle to Grid*) in bi-directional interaction schemes.

In this context, it is necessary to develop interoperability standards for communication and control between different distributed resources (e.g. between different brands of electric vehicles, as well as charging stations and systems). The delegated act on interoperability to be published by the EC before the end of 2020, in application of the provisions of Directive (EU) 2019/944, will be very relevant in this field.

In addition to the need for interoperability between the different distributed resources, a full development of this business model may need to be accompanied by complementary measures related to charging infrastructure and control systems, and to facilitate cross-border travel of electric vehicles (*e-roaming*). In addition, these V2G applications will make energy management in buildings more complex and will provide tools for improving efficiency.

4.4. Cybersecurity

A good part of the installed infrastructures were designed considering aspects such as the physical integrity of the networks, but without considering other issues that have arisen nowadays such as digitalisation and hyperconnectivity, which require a high capacity to share information in a reliable and flexible manner, with the consequent difficulties of adapting to the new cyber security requirements. It is therefore necessary to promote a proactive response to cybersecurity by all actors, in an area where

The dynamic nature of the system means that its procedures must be constantly updated and revised. In this way, robust and creative solutions can be found and provided in harmony with future requirements for the protection of infrastructures and information, and user data, since the exchange of their information with the outside world could pose cyber-security risks for non-specialists (domestic or from other sectors).

4.5. Challenges related to sectoral integration

The decarbonisation of the energy system implies a change of paradigm in its design, in which it will move from a structure composed of unidirectional relations between energy vectors and final consumption, towards a vision of the system as a "whole" with a network of multidirectional interactions. The need for greater electrification of the energy system, placing energy efficiency at the centre, the transformation of the traditional role into an active one on the part of consumers, the digitalisation already mentioned, or the use of renewable energy carriers such as green hydrogen, are all necessary for the decarbonisation of certain sectors such as transport or industry. This transformation will bring with it the need for a wide deployment of storage systems to meet the new needs for flexibility in the energy system in order to guarantee security of supply.

In this respect, the integration of the energy system will require an approach that addresses the various energy sectors in a comprehensive and coherent manner, and exploits the synergies between electricity, heat and gas, although this is a long and complex process. These synergies are enhanced by new technologies and increased consumer participation in energy markets. In the scenarios to 2050, an increase in electrification is proposed, as well as the use of electrolysers. Thanks to the flexibility on the end use side and the dedicated renewable gas storage (hydrogen and others), the operational management of electrolysers could be adapted to the system conditions. Existing storage and transport facilities may need to be adapted for gases such as biomethane or hydrogen. It would therefore be appropriate to advance solutions for the transport of renewable gases beyond the existing natural gas network itself.

On the other hand, there is room for improvement in integrated vector planning and energy system operation. The consideration of power-gas-heat interconnections in sectoral planning (e.g. network expansion) should be improved.

However, sectoral integration, and in particular *power-to-X*, faces some specific risks:

- The disadvantage of *first-mover*: developers of coupling technologies for renewable sectors and gases generally face high infrastructure connection costs.

- Quality and safety standards: standards developed in a context where the only type of gas was natural gas, now impose conditions or limits and the market faces uncertainty about safe injection for several renewable and low-carbon types of gas. In this sense, it is worth mentioning that the current regulation allows a mixture concentration of 5% by volume of hydrogen from non-conventional sources for injection into the gas network. However, it has been demonstrated that at slightly higher volumes, the injection of hydrogen into the network does not have negative consequences, with the only requirement being to adapt burners and valves to suit the characteristics of the gas.

4.6. Challenges for research and development of storage technologies

Storage technologies have a number of positive externalities for developers and society in general, which are usually not sufficiently internalised. Consequently, investment in research and development is an essential factor due to its high added value, especially when there is an opportunity to exercise global technological leadership in a highly competitive international context. As a result of the above, although the costs borne by the developer may be lower than the benefit to society, they are likely to be higher than their own. This can lead to a situation of underinvestment in R&D&I.

Prototypes and pilot projects face the same permit requirements as fully mature and consolidated large-scale projects. However, complying with conventional permit requirements can be a barrier to demonstration projects, due, among other things, to the lack of existing standards for technologies under development, which can result in a loss of competitiveness. Therefore, it is considered that pilot and demonstration projects need specific and simplified permitting processes that accelerate and reduce the costs of the development cycle, with the aim of acting as a catalyst to undertake advanced projects in a more efficient way that accelerates learning for all stakeholders.

In this regard, Royal Decree-Law 23/2020, of 23 June, which approves measures in the field of energy and other areas for economic recovery, introduces an additional provision in Law 24/2013, on the Electricity Sector, which allows for the establishment of regulatory test benches for the development of pilot projects to facilitate research and innovation in the field of the electricity sector. Furthermore, the Royal Decree-Law establishes, by amending Article 53 of the Electricity Sector Act, the possibility of creating a specific authorisation regime for installations whose purpose is research and technological development, so that these do not have to undergo the ordinary procedure.

4.7. Behavioural challenges, lack of information or risk perception

The changes associated with a transition from a traditional model to a more sustainable one sometimes produce a certain reticence, both at a social level and in terms of the business culture of various organisations. The deployment of self-consumption or the exploitation of the opportunities of new business models associated with energy storage can be hindered by this reluctance which generally accompanies change processes.

With regard to smaller-scale and distributed storage, the investment and consumption preferences and decisions of domestic users are geared differently to other actors and pose specific challenges:

- Access to information: with regard to cost information, it is key to be able to correctly compare the costs of different technological options. For example, there is an information barrier if the components of the invoice are not comparable.
- Risk perception: It has been identified as relevant that certain consumer profiles have the perception that adequate physical storage may not be available, or that they will not have sufficient capacity for the amount of energy they need. There is also a perceived risk regarding the evolution of acquisition, operation or maintenance costs.
- Consumer perception of safety and sustainability: these may have the potential to increase consumer willingness to accept and change technology. However, this information is often only incompletely available to consumers.
- Behaviour or inertia: consumers may refrain from adding a new element to their facilities (even if it is profitable) because they prefer to stick to what they know, to the detriment of possible more rational (economic) decisions in the long term (e.g. high initial investment costs versus lower operating costs).

There is also another important challenge in relation to resistance to change in business culture. Many organisations related to the electricity sector are facing a new environment characterised by hyperconnectivity and digitalisation, to which they will have to adapt appropriately. This adaptation process will be more effective if tools are available to facilitate a progressive change of model, based on successful experiences, providing the necessary guarantees to provide certainty and security to all agents involved.

4.8. Social and environmental challenges

Recently, some debate has emerged concerning social acceptance in relation to energy storage. In particular, there have been specific cases of opposition to projects of energy storage in batteries, questioning aspects related to their safety. These systems, like any other technology, comply rigorously with the applicable industrial quality and safety regulations, which provide the necessary framework for both aspects to be guaranteed. However, given this reality, it will be necessary to use the necessary tools to transfer these guarantees to the end user.

On the other hand, certain storage technologies have associated environmental impacts that need to be understood and mitigated. For example, batteries may require access to limited natural resources during the production stage, whose extraction, essential for the development of these technologies, also has relevant environmental consequences. Nevertheless, correcting the associated impacts is an intrinsic part of any extractive project.

For its part, the construction of new pumping projects can have significant impacts on the environment due to the alteration of the water regime and the landscape, although they are subject to environmental legislation, the aim of which is to guarantee a high level of environmental protection, ensuring environmentally viable alternatives and preventing, correcting and, where appropriate, compensating for adverse effects.

Another issue to take into account in the case of a massive implementation of storage is related to the subsequent recycling and treatment of its components. Currently, the degrees of recyclability of storage technologies can be improved, taking on greater importance as progress is made in the large-scale implementation of these systems. In this sense, it will be necessary to pay attention to the potential uses of storage systems at the end of their useful life. The second life of batteries or the recycling of part of their materials for the manufacture of new components presents a challenge as well as an opportunity for new business models.

On the other hand, the technological deployment of storage will require a high number of professionals for the design, installation, operation and maintenance of the systems. One of the challenges is to have adequate training, qualification and retraining of professionals in the industrial and energy sectors at all stages of the value chain, including the supply of components, equipment manufacturing, provision of all types of services related to storage, as well as in the stages associated with the end of the life cycle, where qualified professionals are required in the field of reusing and recycling the systems. In addition, it will be necessary to update current training plans to cover the new needs of future professionals at all levels of training, university degree, master's degree and professional training, so as to guarantee adequate professional qualifications.

4.9. Critical and strategic materials

In relation to the previous section, one of the challenges to be taken into account in the energy transition is precisely the shortage of so-called *critical* materials (CRM) and so-called strategic *materials*. These elements are necessary for some of the technologies essential for making the transition to a low-carbon energy system, as clean energy technologies require a greater amount of materials than conventional ones.

The World Bank document "*Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition*" analyses the consumption of minerals necessary to meet the demand for technologies associated with the energy transition with the 2050 time horizon, including storage technologies, which will have a significant demand for materials such as cobalt, lithium or graphite in the case of batteries. In conclusion, attention will need to be paid to the needs for mineral substances, taking into account the reduction in the use of materials for the same performance as technological developments and innovative applications are brought to market, as well as the reuse and recycling of these components.

5. LINES OF ACTION OF THE STRATEGY

FIGURE 8. Lines of action of the Energy Storage Strategy

5.1. Regulatory framework

Legal regime for storage[5]

The first step has been taken with the introduction of the concept of storage into the national framework, through the incorporation into Law 24/2013, on the Electricity Sector, of the definition of the owner of storage facilities, through Royal Decree-Law 23/2020, of 23 June, which approves measures in the field of energy and other areas for economic recovery.

[5] For the development of the measures included in this Strategy, the necessary coordination between the Government and the National Commission for Markets and Competition will be ensured, in order to give coherence to the necessary regulation within the corresponding areas of competence.

Measure 1.1. Consistent definition of storage in the national legal framework
The first stone has been laid on the road to incorporating the concept of storage into the national legal system. On this basis, it is necessary to adapt the rest of the derived regulations in order to develop all aspects relating to this figure, as well as the services associated with it. This will be done by examining the opportunities provided by stockpiling, identifying regulatory gaps that may be a barrier to its deployment, and analysing possible changes needed to standards and existing products and market models. In addition, the potential and need to define system adjustment services and products at the distribution network level will be assessed.

Measure 1.2. Define the role of the operators of storage facilities and the services that can be provided by the different actors
Establish the role and responsibilities of the figures associated with the ownership and operation of storage facilities, avoiding these figures being penalised by having to be assimilated into the existing ones. In addition, and in accordance with the provisions contained in Directive 2019/944, it is necessary to define the services that may be provided, in relation to this figure, by both regulated (TSO, DSO) and non-regulated agents, and in particular those recently created figures, such as the independent aggregator or the energy communities, which have a great potential to play a very relevant role in this respect.

Article 32 of Directive 2019/944 calls on Member States (MEMS) to provide the necessary legal framework to encourage the use of flexibility in distribution networks.

Measure 1.3. Define flexibility services at distribution network level
Changes to the regulatory framework will be needed to allow and provide incentives for distributed resources to offer flexibility services to distribution system operators, and to define requirements and obligations tailored to distributed storage assets, including *behind-the-meter* assets such as storage and generation by *prosumers,* electric vehicles or manageable demand. This framework should provide for the possibility of storage systems providing several services simultaneously, establishing regulation in this sense. Article 32(3) and (4) of Directive 2019/944 contains elements aimed at increasing the transparency of the need for flexibility services by distribution companies.

Measure 1.4. Modify Operating Procedures to incorporate storage participation
Changes are currently being made to the Operating Procedures to integrate the storage assets. These include • Inclusion of the term storage. • Until the regulatory framework for storage is fully developed, its treatment in the measurement system will be similar to that of generation facilities. • Participation of the storage units in the balance sheet services on the same basis as the generation and pumping consumption programming units. • Organization of the programming units (consumption and injection) adding the requirements of communication of unavailability affecting their physical units. • Treatment of the identified congestion in the generation evacuation with storage programming units present in the same node. • Clear definition of the processes for the technical qualification of networked storage systems and the specific criteria for carrying out quality checks on the telemetry of physical storage units. • Assess the creation of new administrative procedures for low-capacity units.

Reduction of administrative barriers

One of the barriers identified for the effective deployment of storage systems is related to the possible burdens that certain administrative procedures may entail. The need to remove this type of barrier has already been foreseen in Royal Decree Law 23/2020, which has included several provisions aimed at improving and simplifying, inter alia, the procedures for authorising the construction, extension, modification and operation of electrical production, transmission and distribution facilities.

In addition, with the aim of promoting innovation and competitiveness, this Royal Decree-Law introduces a simplification in the administrative processing of those facilities that are considered R&D&I projects. Along the same lines, the aforementioned Royal Decree-Law provides for the creation of regulatory test benches, or "*sandboxes*", in which pilot projects are developed in order to facilitate research and innovation in the electricity sector.

Measure 1.5. Simplification of procedures and reduction of administrative burden
The first steps have been taken towards the elimination of administrative barriers by simplifying, in general, certain procedures relating to electrical energy installations. In this respect, the regulatory framework for storage will define, among other things, the procedures that will serve as a channel for administrative procedures for this type of facility, and will be developed on the same basis of simplification and reduction of burdens. In addition, the simplification of procedures for R&D&I facilities will give a boost to this type of initiative, and the creation of regulatory test benches, explained in detail in **Measure 1.9,** will allow for the introduction of new developments, exceptions or regulatory safeguards which will help to facilitate research and innovation in the field of storage. Finally, regulatory changes and any other measures that may be necessary, within the scope of the different public administrations, should be promoted to facilitate the management and obtaining of grants, permits and licences.

Avoiding duplication of tolls and charges

CNMC Circular 3/2020 of 15 January establishing the methodology for calculating electricity transmission and distribution tolls eliminates tolls for energy storage batteries connected to the transmission or distribution network, in line with Regulation 2019/943.

In the same vein, the draft Royal Decree establishing the methodology for calculating electricity system charges, which specifically excludes storage technologies from payment of charges, was submitted to public participation in July 2020.

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A review process of the storage tariff system is underway with the aim of identifying gaps or weaknesses. In particular, it is necessary to avoid double taxation or double payment of tolls and charges, so that they are not applied so much when storing energy from the network, as when returning it. In addition, given the increased integration of the energy system, it will be necessary to analyse the need to homogenise the charges between different sectors, in order to avoid distortions in the cost of decarbonisation of each of them and to favour synergies between them. The possibility of defining a tool that promotes storage efficiency as it allows the use of surpluses and has a performance in itself will also be assessed.

Transmission network planning

Law 24/2013 makes the planning of all the assets of the transmission grid binding, so that any storage facilities that may be integrated into the grid must be included in this planning. In addition, such planning must take into account the generation and demand estimates provided in the PNIEC.

In particular, in the current development of the 2021-2026 Transmission Network Planning, the use of storage is being analysed as an option to minimise network investments when this technology is a cost-reducing option.

Measure 1.7. Include storage in the planning of the transmission network
Weighing up at national level investments in assets that represent an improvement to the network, considering different forms of flexibility from different resources, and adding security of supply to the requirements to be assessed when considering storage as an alternative, defining storage needs linked to the achievement of the objectives set out in the PNIEC. The ownership, development, management and operation of storage facilities connected to the transmission system shall comply with the conditions set out in Article 54 of Directive 2019/944.

Hybridization and Economic Regime of Renewable Energies

Royal Decree-Law 23/2020, of 23 June, which approves measures in the field of energy and other areas for economic recovery, establishes the possibility of hybridising generation facilities with storage technologies.

The main objective of the draft Royal Decree regulating the Economic Regime for Renewable Energies for Electricity Production Facilities is to promote the development of renewable energies in order to make progress in meeting the objectives of the PNIEC and to pass on directly to consumers the cost reductions that certain renewable technologies can bring about. Its scope of application includes renewable installations with storage, and it can therefore be used as a further element to promote storage.

Measure 1.8. Development of hybrid facilities with storage
The hybridisation of storage systems with renewable generation technologies allows for an increase in the efficiency of the installations for an optimum use of the renewable resource. Also, the possibility of arbitrage can improve the market share of renewable technologies in the case of hybridisation with energy storage. It is therefore appropriate to develop and adapt the regulatory provisions necessary for the development of hybrid installations with storage, which will require clarify, among other things, the tolls and charges applicable to cases where the

energy storage is combined with renewable generators that receive a specific remuneration scheme.

The Draft Royal Decree regulating the Economic Regime for Renewable Energies for electricity production facilities, based on Royal Decree-Law 23/2020, provides for the launch of calls for tender for the granting of the economic regime through competitive tendering procedures. These auctions may distinguish, among other aspects, between different generation technologies, levels of manageability, technological maturity and those others which guarantee the transition to a decarbonised economy.

In addition, in order to promote the predictability of the auctions, the draft Royal Decree provides for the establishment of a planned auction calendar - which may be updated at least annually and which is aimed at achieving the objectives of the PNIEC 2021-2030 - which will cover a minimum period of five years and will include indicative deadlines, the frequency of the auctions, the expected capacity and the technologies envisaged, where appropriate.

The auction calendar will specifically include auctions for new installations or the repowering of existing ones, with manageable technologies or with storage, as an incentive for the incorporation of associated equipment to provide the necessary services for the electricity system during its operation.

Regulatory sandboxes

As indicated above, Royal Decree-Law 23/2020 provides for the creation of regulatory test benches, or "*sandboxes*", in which pilot projects are developed in order to facilitate research and innovation in the electricity sector.

Measure 1.9. Regulatory test benches for storage systems

Regulatory banks are intended to allow industry testing of new storage technologies, systems and services in a safe and supportive space where stakeholders can test their innovative solutions without being subject to prevailing regulatory requirements.

These mechanisms can also provide a two-way regulatory dialogue between the administration and the regulator, so that existing regulations are reviewed quickly and adjusted as appropriate to allow new agents to enter the market, encouraging the creation of technological *start-ups* by giving them an opportunity to test their business models. Regulation should also introduce timely and proportionate measures to support innovation in the industry.

The regulatory development of this figure will be necessary. This will be done by providing the necessary measures and safeguards to protect consumers and the energy market, such as limitations on their duration, allocation of costs incurred or maximum number of participating consumers, as well as to include criteria for assessing the results achieved.

5.2. Market participation

In order to ensure the proper installation and use of the different storage technologies as they are needed, it is essential to ensure that storage facilities can actively participate in the different existing market mechanisms.

Regulation 2019/943 lays down certain provisions to facilitate the participation of operators which will make the system more flexible and effective, including, inter alia, the reduction of the size of products (Article 8).

This participation will provide incentives for investment in storage, making it possible to meet the targets for storage and integration of renewable energies established in the PNIEC and the draft ELP, always in accordance with analyses of compatibility with the EU regulatory framework.

Measure 2.1. Participation of storage in the complementary services and markets of the electricity system
The necessary regulatory provisions will be adapted in order to adapt the different markets to the participation of the storage facilities, so that they can participate in the Daily Markets, Intraday Sessions, Continuous Intraday Market, and eventually, in the local markets, as well as in the different complementary services (secondary and tertiary regulation and deviation management), while guaranteeing a fair and effective competition with the agents already existing in the market. In general, the incentives for energy storage systems are higher the higher the temporal and spatial granularity in electricity markets. In this sense, the provision of appropriate market signals will be encouraged to provide incentives to build capacity and provide storage services as they become necessary. As provided for in Article 32 of Directive 2019/944, flexibility mechanisms will be designed, specifying the services to be regulated by a market mechanism and allowing for broad participation by all players, including storage. Once the figure of operators of storage facilities has been created by legal authorisation (RD-Law 23/2020, of 23 June), the Operating Procedures will be adapted, in line with Measure 1.4. and the Market Rules for the effective integration of storage into the aforementioned mechanisms.

The methodology for carrying out the coverage analysis is currently being approved. It will be the result of this methodology that will subsequently enable a Member State to set up a capacity mechanism.

Measure 2.2. Capacity mechanisms
After evaluating alternative measures in accordance with European regulations, develop appropriate capacity mechanisms for storage participation, so as to provide incentives for the effective deployment of storage compatible with the fulfilment of the objectives established in the PNIEC.

Action 2.3. Participation in balance sheet services
Adapt the regulation for compliance with the conditions relating to the Resolution of 11 December 2019, of the National Commission for Markets and Competition, which approves the conditions relating to the balance sheet for suppliers of balance sheet services and the parties responsible for settlement in the Spanish peninsular electricity system. In particular, owners of energy storage units will be allowed to become providers of balancing services, as well as the aggregation of demand facilities, energy storage facilities and electricity generation facilities into one programme area to provide balancing services.

Measure 2.4. Promote dynamic electricity prices and network tariffs based on time of use
While the Voluntary Retail Price (VRP) is already a dynamic price, measures to encourage the introduction of dynamic pricing by traders, i.e. the price varying hourly, if they do not offer it themselves, will be considered in the framework of the transposition of Directive (EU) 2019/944 of 5 June 2019 concerning common rules for the internal market in electricity, in order to encourage storage behind the meter.

Measure 2.5. Local markets
One way of implementing Article 32 of Directive 2019/944 is through the implementation of local markets managed by the electricity market operator on which, in the event of the existence or foreseen existence of congestion, the distribution system operator has the possibility of obtaining the flexibility services described in **measure 1.3**. In the case of resolution of specific bottlenecks, the functioning of these markets would be similar to that of the existing wholesale market, with energy and price offers by flexibility providers (e.g. aggregators). In the case of persistent congestion, the creation of specific flexibility services between the distribution system operator and flexibility providers could be considered. In both cases, reinforced coordination between the distribution system operators and the system operator will be necessary. In this context, the potential role of distributed storage in local markets will be analysed, as well as the need for visibility of both distributed resources

willing to participate in these local markets (with the possibility of creating a register of distributed resources) as well as the flexibility needs of the distribution system operators (which should be reflected in the development plans mentioned in **measure 1.3**).

Measure 2.6. Reversal signals for storage systems

The different signals for investment in storage should be established on the basis of the analysis of actual needs for storage capacities/services for the different time horizons (short, medium, long term), and always in accordance with analyses of compatibility with the EU regulatory framework.

The necessary investment signals will be given, at the right time, both in the present and in the future, to cover in time, at least, the objectives/needs defined in the PNIEC.

The need for integration into the regulations of Non-Peninsular Territories (Royal Decree 738/2015, of 31 July, which regulates electricity production activity and the procedure for dispatch in the electricity systems of non-mainland territories) will be assessed if a general framework for auctions of storage or generation technologies combined with storage is defined.

FIGURE 9. Lines of action: regulatory framework and participation in the markets

5.3. Business model

In addition to guaranteeing equal participation of storage in the different existing markets and services in which it can make a contribution, the characteristics of storage allow it to be a catalyst for the promotion of new business models that facilitate its deployment and add value to the different elements of the energy transition. This requires an updated and open regulatory framework that allows and encourages this innovation.

An example is the involvement of storage in conjunction with generation and consumption systems to provide more complex services or combinations of services through aggregation. In this respect, Directive 2019/944 of the European Parliament and of the Council of 5 June 2019 concerning common rules for the internal market in electricity and Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 concerning the internal market in electricity provide for the definition of aggregation, through the combination of multiple consumption and market participation through the figure of the independent aggregator.

In the national framework, Royal Decree-Law 23/2020 of 23 June, which approves measures in the field of energy and other areas for economic recovery, introduces the figure of the independent aggregator into the national legal framework.

Measure 3.1. Promote the figure of the independent aggregator
In addition to the latest legislative modifications, it will be necessary to determine the functions of the service aggregator, its responsibilities and demand participation, as well as to encourage distributed systems of individuals participating in the different markets. The figure of the independent aggregator will include storage centres, energy managers and sectorally integrated systems. In this sense, it will make it possible to maximise the use of distributed energy resources and the synergies derived from applying sectoral integration, as well as to provide an effective response to demand that accommodates renewable variability. Among other issues, the regulation of this figure will determine the relationship between marketer and aggregator, which has proven to be a bottleneck in other Member States.

The potential of the storage systems industry needs to be viewed from a very broad perspective, considering the whole range of possible applications, with special emphasis on the integration of these technologies in all sectors and their interrelationship, paying special attention to sectoral integration.

Strengthen and promote the national storage industry for use in all possible applications
For the deployment of energy storage needed in the transition to a low-carbon economy, it is key to have domestic manufacturers throughout the value chain for the various storage systems, both upstream and downstream, in order to create economies of scale that are able to gradually reduce manufacturing costs while adding value. This process must go hand in hand with the promotion of innovation and technological development. Spain has, in particular, an unquestionable leadership position in the field of thermal storage in its thermoelectric generation plants and a wide potential for growth in this sense, so it is essential to take advantage of this competitiveness and to strengthen the development of this technology, in order to maintain the existing industrial leadership in the electricity generation sector, as well as in the different applications that thermal storage provides. Likewise, the maintenance of leadership in the power electronics sector and the development of hydraulic pumping systems will be promoted.

Measure 3.3. Promotion of national self-sufficiency in raw materials or basic components
Some of the raw materials used in the domestic system manufacturing industry The storage facilities depend on the external supply of raw materials and compounds. In some cases, these elements are within the so-called

critical minerals. This makes it necessary to support the strengthening of a fabric of national supplies, with high added value, international projection and high capacity to generate employment.

In the case of natural mineral resources, through the sustainable exploitation of deposits of the more than 70 minerals and rocks that can be found in the country, and in particular lithium or rare earths, it will be possible, for example, to manufacture batteries for the electric vehicle or to digitise the economy.

In order to promote sustainable self-supply, the aim will be to enhance the value of the country's rock and mineral resources, reducing dependence on third countries, contributing to the maintenance of the population and activity in rural areas with problems of depopulation and encouraging rational land use, mainly in the rural environment.

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The amendment of Directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators is currently in progress. One of the issues under review is the possibility of giving batteries a second life, which is not covered by the existing Directive.

Measure 3.4. Promote the second life business model for batteries

A significant increase in the number of batteries to be used in second life is expected. They will be used in sectors where the reduction of battery performance and efficiency is not an obstacle to achieving acceptable profitability. The potential for use of these systems can be found in various applications, such as irrigation and livestock farming, network reinforcement services, especially for the demand for fast charging to cover peak loads, forklifts or applications in the tertiary sector.

One of the challenges to be addressed in terms of the second life of batteries is the creation of standards for the testing and characterisation of batteries in their second life. The development of this sector presents important leadership potentials for the national industry.

This measure is closely related to **Measure 8.3. Circular Economy Strategy**.

The storage systems are covered by different UNE technical standards; they are covered, at least, by the following Technical Standardisation Committees:

- CTN 218: Electrical energy storage systems, focusing on integrated electrical energy storage systems in the grid and on the interaction between electrical energy and storage systems.
- CTN 203/SC 21 and CTN 206/SC 105: standardisation and innovation of accumulators and fuel cells.

Measure 3.5. Promote the development of national standards for storage systems

The evolution of the different storage technologies will require the adaptation of the technical and security standards of the different systems, promoting the development of technical standards that favour the provision of a wide range of services to different users.

In addition, strong growth is expected in the use of storage technologies, especially batteries, at the domestic level. This has to be accompanied by security measures to ensure adequate protection for users, as well as measures to promote energy efficiency.

To this end, among other issues, Spanish participation in the international standardisation initiatives that are being carried out in this field must be ensured, as well as encouraging the participation of professionals, both from the public and private sectors, in standardisation training programmes.

The adoption and use of standards in support of regulation and in public procurement should also be promoted.

Commission Recommendation (EU) 2019/553 of 3 April 2019 on cybersecurity in the energy sector proposes the main actions to be taken on the three main issues related to cybersecurity in the energy sector: real-time requirement, cascading effects and combination of traditional and state-of-the-art technologies. It also calls on Member States to encourage stakeholders to acquire knowledge and skills related to cybersecurity in the sector. Consequently, these recommendations should be incorporated into the national cybersecurity framework affecting energy storage.

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The evolution of the different storage technologies will require adapting the security standards of the different systems and guaranteeing adequate protection for users and their data.

It will be necessary to adapt those infrastructures already in place, whose original design envisaged only the physical integrity of the networks, to the new security requirements arising from digitisation and hyperconnectivity, ensuring the same level of security and data protection for large networks and micro-networks.

This makes it necessary to standardise security protocols in software and hardware, developing specific quality standards for the connected systems that consider cyber security as a design parameter in the installations and applications, at hardware and software level.

Cybersecurity certification schemes will be promoted as stipulated in Regulation (EU) 2019/881 on the certification of cybersecurity in information and communication technologies, as well as future certifications related to the Critical Infrastructure Protection and Essential Services Certification Scheme (ECPICSE).

The dynamic nature of cybersecurity requires a proactive response from all actors that goes beyond mere compliance with current regulations. It must be encouraged:

- The search for robust, creative solutions in harmony with future requirements for the protection of infrastructures and information, and user data. One example of such requirements is the European Commission's recommendations on cyber security for 5G networks.
- The constant review and updating of applicable cybersecurity procedures and standards
- Spanish participation in international initiatives related to the subject.

Cybersecurity training will also be included in academic and professional training plans related to storage systems, in order to address the risk of shortage of human resources capable of covering these services.

The main reference standards for cybersecurity are

- UNE-EN ISO/IEC 27019:2020, Information technology. Security techniques. Information security controls for the energy services industry.
- UNE-EN IEC 61850 Series, Communication systems and networks for automation of generation facilities.
- Series UNE-EN IEC 62351, Power system management and associated information exchange. Data and communications security.
- Series UNE-EN IEC 62443, Safety for industrial automation and control systems.

Interoperability is considered to be the key to balancing the storage potential of electric vehicles and systems behind the meter, for which harmonised system operation and equipment communication standards are required, such as the use of *vehicle-to-grid* technologies, communication protocols in electric vehicle cross-charging infrastructures, among others.

This requires reviewing and determining the applicability, scope and consistency of certification requirements for energy storage communication protocols and systems, so that they are encrypted and authenticated and allow communication with different types of data, so that the different protocols are compatible and ensure cybersecurity, in accordance with the certification requirements for cybersecurity stipulated in Regulation (EU) 2019/881 on the certification of cybersecurity in information and communication technologies.

Likewise, it is necessary to standardise security protocols in software and hardware, developing specific quality standards for connected systems that consider cyber security as a design parameter in the installations and applications, at hardware and software level.

On the other hand, the same level of security and data protection must be guaranteed for large and micro networks.

In addition, it will be necessary to establish norms and standards for smart appliances and other devices in the field of IoT (Internet of Things) in order to ensure their interoperability, maintain privacy and cyber security.

Measure 3.8. Encourage and support participation in international forums of national industry

The development of storage systems gives national companies the opportunity to exercise new leadership on an international level. One of the keys to internationalisation will be the participation of organisations and associations in the main international and European forums.

There are numerous relevant international initiatives linked to the storage sector where there is great potential for participation by Spanish industry; among others: the new Public Private Partnerships (Clean *Hydrogen, Batteries, 2Zero, Clean Sky, Clean Energy Transition Partnership, Driving Urban Transition to a Sustainable Future, Built4People,* etc.) as well as initiatives such as the *European Batteries Alliance (EBA250), Mission Innovation,* etc., to name but a few.

Especially relevant for the deployment of large scale storage or renewable hydrogen related projects is the IPCEI (Important Project of Common European Interest) initiative, where Spanish participation is of great interest.

Measure 3.9. Exploiting the potential of storage in intelligent energy management

The business framework generated must favour the deployment of intelligent energy management systems that allow for the optimisation of renewable generation and active participation in the network and energy markets, taking full advantage of the potential of storage.

The use of intelligent networks, or *Smart-grids* and the Internet of Things (IoT) allows the connection of different elements in a network, offering a series of advantages such as improved efficiency in the use of energy by the equipment connected in an autonomous and automated way.

The integration of advanced energy control systems allows efficient management of all the elements of the installation (e.g. advanced building control and automation systems and their technical services). These systems must include algorithms for predicting generation and demand and algorithms for optimising the management of controllable elements.

On the other hand, there is a great potential associated with technologies such as the *Blockchain,* which allow safeguarding the massive and secure processing of the necessary data, acting as a guarantee for the participation of the resources distributed in aggregate markets. The Blockchain can in turn "vehicle" intrinsic attributes in terms of energy consumed, stored or generated by the user in their transactions (for example, between *peer- to-peer* pairs) and the renewable origin.

Electric vehicle

The existence of a fleet of electric vehicles makes it possible to make use of a mobile and distributed storage system, which, in an aggregate manner, represents an important potential as a flexibility element, which, when optimised, will reduce the needs for other elements that provide the electric system with flexibility.

Measure 3.10. The potential of the electric vehicle as an element of flexibility

Enable the use of the electric vehicle fleet as a storage resource, which will require the design of network codes, market incentives and support policies to enable the shaping of the charge. The implementation of *On-Board* storage systems for electric vehicles will offer another series of services, using *Smart Charging* and *Vehicle-to-Grid* technologies *(Mobility to Grid and Mobility to Home)*.

In addition, it is necessary to provide a sufficient recharging infrastructure for the massive deployment of this technology in mobility applications. In this sense, the measures to be adopted must include the development of intelligent two-way recharging of the electric vehicle. There is also a need to speed up the processing of applications and permits for the installation of recharging points.

Encouraging public participation in the intelligent management of the electricity system through the electric vehicle is one of the keys to the efficient use of this storage resource. To this end, it will be necessary to establish norms and standards in electric vehicle charging systems so that consumers can participate in the intelligent management of the electricity system and take advantage of the tariff advantages in the charging of vehicles and the "*Vehicle-to-Grid*".

Action 3.11. Take advantage of the "Wave of Renewal" to make storage available in the building sector

The investments associated with the renovation and modernisation of the existing building stock open the door to the use and aggregation of different uses of the storage present in the buildings. In addition to the use of batteries and electric vehicles, there are numerous technologies available to extend distributed storage, such as the use of technologies for storing environmental heat or heat from renewable sources, using the thermal masses of the buildings themselves, the use of geothermal resources, mechanisms for storing sensitive and latent heat (electric boilers, heat pumps, refrigeration with ice storage, etc.) which allow alternative methods of distributed storage to be explored and present opportunities for decarbonising the existing park, while offering flexible solutions to networks through aggregation and integrated management of the building.

Additionally, in new buildings a conceptual approach to projects will be pursued to integrate, from design and promotion, the most efficient and cleanest technologies, including energy storage. The General State Administration has been playing an exemplary role, promoting measures relating to the rehabilitation and improvement of the energy efficiency of its buildings and the integration of renewable and highly efficient technologies to provide them with energy. In this sense, it is necessary to take advantage of the potential of the public building stock for the installation and testing of storage systems, pilot equipment or self-consumption systems, making use of mechanisms such as innovative public procurement.

The revision of the regulation on thermal installations in buildings (RITE), the long-term renovation strategy for the energy renovation of buildings and the development of the Smart Readiness Indicator (SRI) introduced by Directive 2018/844 will play an important role in facilitating the renovation and modernisation of the building stock.

Measure 3.12. Encourage the use of storage for self-consumption

Self-consumption has great potential for the development of distributed storage systems. Therefore, the development of self-consumption in all sectors could result in a strong boost to storage in the whole electricity system. The strategy for self-consumption will take account of the specific nature of these installations, paying attention to those that include storage technologies.

FIGURE 10. Lines of action: business model

5.4. Sectoral integration

Action 4.1. Promote renewable or green hydrogen
Green hydrogen makes it possible to use electrical energy from renewable sources to produce clean hydrogen through the process of electrolysis. Renewable hydrogen can then be used in end uses or as an energy carrier. Consequently, this energy vector can potentially contribute to reducing discharges of unmanageable generation technologies and to providing flexibility to the system, while adding value to hydrogen-intensive industries by reducing the emissions associated with the use of hydrogen from natural gas reforming (also known as grey hydrogen). Identifying the large consumers of hydrogen, mainly focused on the industrial sector, and facilitating the progressive supply of hydrogen of renewable origin, would encourage its gradual decarbonisation, while allowing the maturation of the electrolysis technology, until reaching a greater energy efficiency and a lower cost of installation and operation. The Hydrogen Roadmap: a commitment to renewable hydrogen6 includes specific measures to promote this fuel and its contribution to mitigating climate change and greenhouse gas emissions.

Measure 4.2. Public initiative to create a green cluster for the technological and industrial development of storage in Spain
Open to participation and with the aim of integrating different companies in the energy sector's value chain, giving a boost to the competitiveness of the industrial fabric and allowing, through the use of renewable energies and storage, to contribute to the decarbonisation of the companies that make up the sector. This cluster also has the potential to open up to energy-intensive industries, incorporating them into its activity, taking advantage of synergies and maximising the benefits associated with sectoral integration.

Measure 4.3. The potential of *Power-to-X* development
Power-to-X systems (*Power-to-Gas* and *Power-to-Liquid*) allow the generation of hydrogen by electrolysis for subsequent use in industry, or for the production of synthetic natural gas from such hydrogen and CO_2, which in turn can be injected into natural gas networks for use in heat generation, for transport, or for conversion into electricity. The electrolysis process makes use either of surplus electricity generation or of specific installations dedicated to its production through renewable generation. This technology, although incipient, has great potential to promote sectoral integration. For this reason, it has become one of the great energy challenges of the future, and its development must be encouraged in order to take maximum advantage of the

[6] https://www.miteco.gob.es/images/es/hojarutadelhidrogeno_tcm30-513830.pdf

opportunities it offers, analysing the main barriers to its deployment.

The key to promoting the development of green hydrogen through *Power-to-X* systems is the establishment of a Guarantee of Origin system, since hydrogen can be produced from renewable and non-renewable sources, with a wide range of greenhouse gas emissions. At European level, the *CertifHy* Project serves as a reference in the traceability of renewable hydrogen.

Measure 4.4. Take advantage of leadership in thermal storage

Currently, there is a renewable storage capacity in molten salt tanks in solar thermal power plants, which contributes to the manageability of the electricity system and the reduction of renewable waste. This storage technology, in which Spain is a leader, has various sectorial integration applications, such as the use of heat for industry or for heating and cooling networks, and significant growth is expected in this technology due to its potential in terms of the services it can provide.

FIGURE 11. Lines of action: sectoral integration

5.5. Citizenship at the centre

FIGURE 12. Lines of action: citizenship at the centre

The "Clean Energy for All Europeans" package includes Directives 2019/944 of the European Parliament and of the Council of 5 June 2019 concerning common rules for the internal market in electricity and Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 concerning the internal market in electricity. These rules, among many other aspects, place citizens at the centre, as a fundamental element in the energy transition, promoting their participation in a flexible and dynamic way through the figures of the independent aggregator or the energy communities.

With the same objective of facilitating the participation of citizens, SMEs and local entities in the energy transition, the PNIEC 2021-2030 includes *"Measure 1.13 specifically aimed at local energy communities"*, which introduces among its action mechanisms, the promotion of demonstration projects of local energy communities covering the widest possible range of cases. This could include various storage systems, identifying and enabling viable business and financing models for the different types of projects, allowing them to be developed on a large scale, as well as bringing them closer to the public.

Royal Decree-Law 23/2020 incorporates the figure of *"Renewable Energy Communities"* into Law 24/2013 on the Electricity Sector. These are defined as entities based on open and voluntary participation, autonomous and effectively controlled by partners or members who are located in the vicinity of renewable energy projects owned by these legal entities.

This figure therefore aims to involve citizens and local authorities in renewable energy projects, which will allow for greater local acceptance of these energies and greater citizen participation in the energy transition.

Measure 5.1. Renewable energy communities
Based on the definition of renewable energy communities and Action 1.13 of the PNIEC, it is necessary to ensure a regulatory framework for these communities to integrate energy storage. These groupings provide multiple opportunities. Amongst other things, they will make it possible to take advantage of the digitalisation of networks to implement new business models related to shared self-consumption, or to carry out other energy uses beyond electricity consumption, such as the generation of biogas in the communities themselves from waste, with the obvious benefits that this would bring, and which could contribute to the reduction of energy poverty. Renewable energy communities and energy citizen communities also offer the opportunity to promote citizen participation in non-traditional financing models of local and mixed systems of renewables and storage behind the meter. In particular, it will be possible to develop new proposals for financial support schemes via *crowdfunding/crowdlending* or collective ownership/financing models, with the potential co-participation of local public authorities and the promotion of other forms of Citizen's Communities. With regard to the participation of local entities, this measure would take advantage of the synergies of the "Governance" Action Line included in this Strategy, and the role of municipal entities as active promoters of these new models but also as "pioneering" investors in distributed storage systems, energy communities and other models yet to be developed, so that these projects take on a demonstrative role that will drag the rest of society into their implementation.

Training

The draft Organic Law for the Modification of the Organic Law on Education (LOMLOE), approved by the Council of Ministers on 15 February 2019 and currently being processed, already contains the concept of sustainable development, together with education for ecological transition.

However, one of the challenges in enabling the deployment of energy storage is related to providing the professionals involved with the necessary tools to ensure adequate knowledge throughout the training and education system.

In this sense, *Measure 1.17* of the PNIEC 2021-2030, relating to *"Training of professionals in the renewable energy sector",* in anticipation of the implementation of new decarbonisation technologies - such as those relating to storage - considers the need to anticipate market demands and promote continuous training at the five levels of approved professional qualification, taking into account that the Single European Market demands training in professional skills that facilitate mobility in the EU.

Measure 5.2. Adaptation of training and curricula
Adapt, transform and create training plans at all levels, from Vocational Training to Universities containing competence standards related to energy storage. In addition, the inclusion of the climate change and energy transition dimension, together with the basic knowledge associated with storage systems, will allow the development of knowledge, skills and abilities related to the ecological transition. The objective of this curriculum adaptation will be the selection of priority sectors that can be an economic driver for the country, including the development and deployment of storage systems. The special incidence of storage in the engineering and architecture sectors, especially in what is associated with the building sector and its energy audit, makes it especially relevant to consider the inclusion of subjects related to storage in their study plans. Similarly, in the case of S&T-related higher education qualifications, the inclusion of these competency standards in the curricula is essential to address the technological gap to be reduced in order to meet the challenges of the future. This action will be accompanied by the promotion of the participation of professionals from both the public and private sectors in training programmes in standardisation, so that they can maximise the use of the possibilities offered by the development of a standardisation strategy within the overall strategy of the organisations. Due to its growing relevance in the field of energy storage, it is essential to link the above measures with training in cyber security, blockchain, IoT (Internet of Things) and artificial intelligence to solve the risk of shortage of human resources capable of covering these services in energy storage.

Measure 5.3. Qualification and certification of installers in the residential sector
The deployment of storage in the residential sector requires training adapted to the training needs of installers of this type of technology. To this end, it will be necessary to work hand in hand with the sector to make the most of the opportunities it offers to meet the sector's training needs. Complementarily, it will be necessary to work on the provision and accessibility of these services by clients living in remote areas and those with low accessibility for geographical reasons.

For its part, the Regulation on Thermal Installations in Buildings (RITE), currently under revision, has a specific working group relating to the group of installers in the residential sector, where discussions, dialogue and proposals for improvement in this regard are welcomed.

In addition, it would also be interesting to consider other professional groups, such as property administrators, as a direct link with the communities of owners.

Dissemination, awareness and participation

Another of the key issues for the effective deployment of storage and social acceptance lies in promoting adequate dissemination, awareness and participation in relation to energy storage, in line with the PNIEC 2021-2030, in *"Measure 1.14 Promotion of the proactive role of citizens in decarbonisation"*. In this sense, the objectives of empowering citizens, improving their capacity to make choices, mobilizing and channelling available funds to the renewable energy transition and promoting citizen participation in the definition of local, regional and national energy policies will be addressed.

Make the general public aware of the potential of storage in a broad sense.

Encourage public participation in the deployment of storage technologies, especially behind the meter, which has great potential for this.

Promote forums for sector participation in the development of storage, with the aim of making the most of its virtues and advantages.

In accordance with the precepts established in Articles 23 and 24 of Directive 2019/944, access to energy data by citizens will be promoted, guaranteeing the protection of their data in accordance with Organic Law 3/2018, of 5 December, on the Protection of Personal Data and the guarantee of digital rights.

In line with this, maximum transparency in terms of consultation and price awareness will be ensured.

It will also encourage all companies' environments with users' personal data to be secure environments.

In this sense, Measure 4.6 of the PNIEC contemplates a series of action mechanisms to achieve this end.

Just Transition

The Just Transition Strategy is one of the three fundamental elements which, together with the Draft Bill on Climate Change and Energy Transition and the Integrated National Energy and Climate Plan 2021-2030 (PNIEC), make up the Strategic Framework for Energy and Climate, presented in February 2019 by the Spanish government. Its objective is to establish a strategy of solidarity-based support to ensure that people and regions take full advantage of the opportunities of the energy transition, so that no one is left behind in a context of growth in renewable energies and the closure of thermal power stations, coal mining and nuclear power stations.

This strategy has materialised in the development of the Just Transition Agreements; the Agreement for a Just Energy Transition for thermal power plants in closure; the implementation of mining and power plant labour exchanges; the development of aid lines for business projects and town councils in areas affected by closures; or Royal Decrees Law 17/2019 and 23/2020 on procedures for granting access and connection permits in just transition nodes and the concession of water in the geographical area of the facility; among other lines of action to guarantee a just transition.

These actions are reinforced by the European Union's Just Transition Facility, which aims to help mobilise at least EUR 100 billion over the period 2021-2027 in the most affected European regions, through three funding mechanisms: the Just Transition Fund, the specific InvestEU Transition Facility and a European Investment Bank public sector lending facility.

In this same context of energy transition, the PNIEC establishes the development of energy storage as a key objective for integrating large-scale renewable generation into the electricity system. In addition to its benefits in terms of flexibility and manageability, storage implies the generation of employment, economic activity and innovation in the territories where it is implemented, proposing synergies with the needs of the areas in the process of fair transition. The link between the Energy Storage Strategy and the Just Transition Strategy is therefore clear.

Measure 5.7. Promote storage projects in Just Transition areas

The implementation of storage projects in the Just Transition areas will be promoted, taking advantage of the endogenous resources of the territory.

In this way, the generation of employment, economic activity and innovation that these projects will bring to the territory will help to reduce the socio-economic impact of the closures of thermal power stations, coal mining or nuclear plants in these areas, in the context of the energy transition.

In addition, in the development of these projects, access to the mining and thermal power plant employment exchanges set up by the Just Transition Institute will be promoted and encouraged, with the aim of maximising the positive impact of these actions on the employability of workers affected by the closure of coal mines and power plants. The main objective is to generate positive socio-economic impacts, which do not provoke social rejection, with important environmental improvements and which at the same time fix the population in these areas.

The Fundación Ciudad de la Energía - Ciuden, F.S.P., attached to the Just Transition Institute, is a state public sector foundation, dependent on the Secretary of State for Energy of the Ministry for Ecological Transition and the Demographic Challenge, designed to implement energy-related R&D&I programmes. Ciuden is a powerful tool for the implementation of pilot projects aimed at supporting the achievement of the PNIEC's objectives, acting as a platform for the development of energy storage technologies.

Specifically, its lines of work focus on the analysis of the entire energy storage chain, the evaluation of flexibility solutions, the analysis of the role of storage in sector integration, the development of advanced energy management systems, the study of hybrid systems and the scaling, validation and integration of systems in real operating environments.

Measure 5.8 Promote R+D+i initiatives in Just Transition areas through CIUDEN

The Energy City Foundation - CIUDEN, F.S.P., attached to the Just Transition Institute, will be able to promote research, development and innovation initiatives in energy storage in Just Transition areas, in order to boost innovative solutions in storage technologies while acting as a technological lever for the areas affected by the closures.

These initiatives may also act as a tool for fair transition, by encouraging the conversion of disused energy facilities previously linked to coal-fired generation or by promoting storage projects in areas affected by closures, thus bringing significant benefits to these regions.

It will be studied how the use of the Just Transition nodes or other infrastructures of the electricity system in Just Transition areas can contribute to the best development of the lines of action of the Strategy, in order to meet the storage and manageability needs of Spain and the regions affected by the closures.

5.6. The levers of technological development

FIGURE 13. Lines of action: the levers of technological development

Improving approaches, skills and knowledge

Measure 6.1. Promote the creation of experimental and research laboratory platforms that exploit synergies
The existence of a dispersed network of laboratories makes it necessary to make it possible to pool testing resources through experimental and technological platforms, open to all actors in the sector, which create synergies, allow efficient use of resources and facilitate the distribution and exploitation of results. In this sense, Spain already has initiatives such as the Spanish Technological Platform for Energy Storage - BatteryPlat, whose general objective is to consolidate the main Spanish actors working in all energy storage technologies, in order to promote a vision

and to develop a strategic research agenda to accelerate the innovative development of the sector in order to place it at the forefront of the world.

Among other benefits, these initiatives can result in a significant strengthening of Spanish industry throughout the value chain, by boosting technology transfer, allowing the manufacture and assembly of key parts and components in these systems to be brought to Spain. To this end, it is necessary to encourage the creation of companies and strengthen their links with research centres.

For its part, the **Hydrogen Roadmap: a commitment to renewable hydrogen7** includes a measure that envisages the creation, in the medium term, of a Centre of Excellence for energy storage research, with special emphasis on storage using renewable hydrogen.

Measure 6.2. Improving technology transfer

There are significant gaps between knowledge and technology centres and the industrial field, which must be reduced by drawing up a plan to promote the transfer of knowledge and technology, within the framework of the EECTI (Spanish Strategy for Science, Technology and Innovation).

Action 6.3 Quadruple helix initiatives

The implementation of quadruple helix programs, which include the academia, industry, administration and citizens, allows to anticipate and provide professional training before the need for technology implementation arises. To this end, stable and fluid communication will be planned with training and excellence centres on advanced energy technologies, as well as with industry and educational institutions, incorporating all the new developments in storage that exist and are planned in the short term. These initiatives promote the generation of knowledge, so that storage systems can be deployed in industry, transport and construction, among other sectors

European initiatives for the development of storage technologies

There are currently numerous initiatives, both at national and European level, which have great potential to act as levers for technological development and which will enable innovative projects to be promoted.

Among other initiatives, the *SET Plan* (*European Strategic Technology Plan*) is a key instrument for the development of low-carbon technologies to facilitate the transition to a climate-neutral energy system. Its purpose is to enable the improvement of these technologies, reducing costs through the coordination of national efforts, promoting cooperation between countries, companies, research centres, etc.

[7] https://www.miteco.gob.es/images/es/hojarutadelhidrogeno_tcm30-513830.pdf

Another relevant instrument in this sense is *Mission Innovation, a* global initiative designed to promote innovation in clean energy. It is based on the idea that innovation, accompanied by integrated sustainable public investment with a high level of business leadership, allows ideas to be transformed into viable mechanisms, capable of achieving an affordable and sustainable energy system.

The European Battery Alliance (EBA250) is a set of actions aimed at achieving a competitive, innovative and sustainable European battery development and production industry throughout the value chain. Within the framework of the EBA250, a European technological innovation platform has been created (*ETIP-European Technological Innovation Platform) in batteries,* called *ETIP-BATTERIES EUROPE,* which represents the framework for collaboration, or *marketplace,* between all the different European *stakeholders in the* area of batteries, covering the whole value chain of research and innovation in this sector.

Por último, conviene citar las nuevas Public Private Partnership tales como Clean Hydrogen, Batteries, 2Zero, Clean Sky, Clean Energy Transition Partnership, Driving Urban Transition to a Sustainable Future o Built4People, entre otras.

Measure 6.4. Exploiting European and national initiatives to act as a lever for innovative projects
It is necessary to take full advantage of European initiatives such as *SET Plan*, *Mission Innovation* or *EBA 250,* described above, which are designed to promote innovative projects linked to the energy transition and which have great potential to act as a lever for technological development. At national level, cutting-edge technological solutions are already available to industry. Among others, there are initiatives linked to the electric vehicle with battery packs of our own design, which act as a breeding ground to position Spanish industry on the international map.

Measure 6.5. Promote the attraction of European funds for innovation
Revenues from market participation may not be sufficient to pay off investments in such highly capital-intensive projects, and their viability may require additional support. This is why there are, or are being developed, numerous financing instruments, both at European and national level, from the funds available for ecological transition and economic recovery, which can be used for the implementation of storage technologies, either alone or in combination with renewable generation technologies. Annex A to this document contains a brief description of some of them.

Specific actions to accelerate technology maturity (advancing TRLs)

Given the degree of maturity of some of the storage technologies, it is now necessary to have lines of aid to cover the gap with market conditions and enable the development of this type of project. Annex A to this document sets out a series of instruments at both European and national level (such as the call for proposals managed by the IDAE in section 3.1. of Annex A on aid for investment in installations for the generation of electrical or thermal energy from renewable energy sources, eligible for co-financing by Community funds (ERDF).

Measure 6.6. Support measures for the development of pilot projects
In line with measure 1.2 of the PNIEC, design mechanisms that allow the expansion of solutions both behind and in front of the meter. Storage can play a relevant role in certain regulatory test bench profiles as defined by Royal Decree Law 23/2020 or in regulatory demonstration projects as defined by CNMC Circular 3/2019. Public entities such as the IDAE will be encouraged to participate directly in pilot projects and *flagship* projects related to storage.

Measure 6.7. Intensify R&D&I in long-term storage
Improving long-term seasonal storage capacities is necessary to ensure security of electricity supply in periods with a low contribution of unmanageable renewable energy.

Measure 6.8. Strengthen research on technologies behind the meter and their impact on the system
Intensify research to understand the role that storage can play behind the meter, as there is uncertainty about how the massive expansion of solar PV in the residential sector can affect system security at the low-voltage grid level and to what extent storage can provide a solution and turn a potential threat into a flexible service that, by adding multiple pieces of equipment, can resolve congestion situations.

Measure 6.9. Advanced battery research
The Spanish Strategy for Science, Technology and Innovation 2021-2027 includes battery research among its areas of intervention. Research and development of new types of batteries, designs and materials to meet new challenges (XFC or *extreme fast charging*, improved thermal performance, etc.). To intensify advanced research into next generation lithium-ion and sodium-ion batteries. To develop new battery designs that provide high performance in terms of lifetime, improving, among other aspects, the thermal performance of the batteries. Research into new substitute materials, for example, applying advanced support tools such as Artificial Intelligence, *machine learning* techniques or computer acceleration to discover new materials or optimise existing ones.

Measure 6.10. Promote R&D&I in all technologies
Promote R&D&I in thermal energy storage and other technologies. Specifically, thermal energy storage in the residential sector will be key given that

is a low-cost technology with a wide range of energy density improvements that can work as a thermal battery coupled to a heat pump or as a structural part of the building (floors or walls), for example, technologies using phase change materials or thermochemistry in domestic building environments.

Action 6.11. Support for R&D&I in renewable hydrogen value chain technologies

Promote the development of technologies for the take-off of green hydrogen, in line with the Hydrogen Roadmap: a commitment to Renewable Hydrogen[8] , which includes 9 measures focused on boosting R&D&I of renewable hydrogen technologies throughout its value chain.

In this sense, and given that both energy storage and renewable hydrogen are fundamental pillars of sectoral integration and, in general terms, of the decarbonisation of the economy, R&D&I will be coordinated in both technologies, seeking synergies and maximising positive results and effects in terms of competitiveness, innovation and internationalisation.

5.7. Sustainability

Traceability: a life-cycle approach to sustainability

Measure 7.1. Traceability of the origin of suppliers and end of life of the waste

Establish rules on the origin of suppliers to ensure compliance with environmental, geostrategic and social justice requirements.

Study the possibility of implementing standards in relation to the minimum criteria to be met in certain areas (environmental, social, labour, etc.) for suppliers of raw materials and critical components. Study the implementation of the equivalent of a Corporate Social Responsibility system for suppliers, so that it impacts on life cycle analysis, and boosts the competitiveness of national industry.

The concept of green purchasing has already begun to spread in the area of the General State Administration. It is increasingly common to find in public procurement specifications requirements relating to the implementation by suppliers of environmental and occupational health and safety management systems

Measure 7.2. Improve waste management of spent batteries

In order to manage spent batteries efficiently and safely, it is necessary to advance in the definition and implementation of a system of notification, verification and validation of spent batteries.

In addition, it is necessary to improve waste collection and recycling flows, establishing reliable traceability systems and monitoring indicators.

8 https://www.miteco.gob.es/images/es/hojarutadelhidrogeno_tcm30-513830.pdf

At European level, work is being done to review and update the legislation applicable to batteries, integrating eco-design, improving aspects such as increasing collection rates and, in general terms, adapting the legal framework to the current model, in which strong growth is expected in the battery sector.

Circular economy

Measure 7.3. Circular Economy Strategy
To work on the improvement of waste collection processes through the implementation of material recycling and system reuse plans (second life of batteries), in order to increase collection and recycling rates. These developments will be implemented in coordination with the Action Plan derived from the Circular Economy Strategy. Encourage the priority use of secondary materials to reduce dependence on foreign raw materials.

Measure 7.4. Promote business models aimed at the recovery of waste from storage technologies
Spain today needs to export its waste to other countries so that they can deal with its recycling (e.g. Li-ion, Cd, etc.) It is an opportunity to review the business model and generate a favourable environment for the development of a sector related to the implementation of business cases in the field of the circular economy.

Critical materials

Measure 7.5. Critical materials
The deployment of storage systems has to meet the challenge of reducing the European Union's dependence on the import of raw materials. The batteries contain five materials (cobalt, nickel, lithium, graphite and vanadium) that are strategic, with cobalt, graphite and vanadium appearing on the list of Critical Raw Materials established by the European Commission due to their importance in the economy (volume of end users and contribution of added value) and the supply risk (concentration of suppliers and type of supplier countries). In this context, Spain is faced with the challenge of researching, developing and promoting the battery industry and the industry of the mineral raw materials essential for its manufacture, in particular by strengthening its own resources (e.g. Lithium, Vanadium, Nickel, Cobalt, Graphite and Rare Earths).

FIGURE 14. Lines of action: sustainability

5.8. Needs in island and isolated 5.8. systems

Island systems have unique storage needs due to their energy isolation and low interconnection, so storage solutions are more pressing than on the mainland to allow greater integration of renewables in the electrical and thermal sectors, as envisaged in measure 1.12 of the PNIEC 2021-2030 aimed at *"Unique projects and strategy for sustainable energy on the islands"*.

This situation also presents an opportunity to test the needs in terms of resilience to undertake a complete decarbonisation of the energy system on a smaller scale.

Among the most recent initiatives to provide energy storage for island systems are the calls for proposals SOLBAL and SOLCAN9 , by IDAE to promote the deployment of renewable photovoltaic technologies on islands. In these calls, 60

9 https://www.boe.es/boe/dias/2020/07/02/pdfs/BOE-B-2020-19901.pdf

million to promote this type of facility, and among its assessment criteria is the availability of storage systems.

Measure 8.1. Generate incentive mechanisms for the deployment of storage in island and isolated systems
Define mechanisms aimed at the deployment of flexibility resources that include storage technologies. In areas with a low level of interconnection, incentives will be provided for the creation of supply call mechanisms for intermittent renewable energy operators that integrate both storage and production systems.

Measure 8.2. R&D&I in isolated and low-interconnection areas
Island territories are a breeding ground for experimentation, as are areas with limited network interconnection. They will be, inter alia, priority areas for the implementation of pilot projects, such as regulatory test beds.

Measure 8.3. Use storage as a source of technological and industrial development
Favouring an industrial and technological environment specialised in storage that will relaunch employment, technological development and industry in island and isolated areas.

5.9. Governance

Measure 9.1. Involvement of regional and local authorities
Encourage the participation of different types of local and regional authorities (Autonomous Regions, town councils, etc.) throughout the implementation of the Strategy, in order to provide a vision that is closer to the citizens and to transfer the problems that may arise in this regard.

Measure 9.2. Monitoring the development of the Energy Storage Strategy
Monitoring of the strategy with the involvement of the different agents in the sector together with the Ministries involved in order to follow up the implementation of the strategy, ensure coordination with the other plans in force and detect good practices and shortcomings that serve as a basis for continuous improvement in the energy transition process. Analysis of the challenges and opportunities presented by storage over time, as well as the measures to be updated and developed for effective storage deployment For all this, CIUDEN is configured as a tool of the Administration that will allow the monitoring of technological development related to storage,

serving as a point of contact between industry, technology centres and the Administration itself.

Measure 9.3. Update of the Energy Storage Strategy

In order to ensure an appropriate follow-up and update of storage needs, the Energy Storage Strategy will be monitored and updated in coordination with the updates of the National Integrated Energy and Climate Plan, in accordance with the timetable set out in Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the governance of the European Union's energy and climate action.

Measure 9.4. System for monitoring and data management by the Administration

Adaptation of the administrative records for the effective integration of storage facilities, in order to have a consolidated, complete and reliable database that allows for the correct monitoring of the evolution of the deployment of the installed storage capacity and its typology.

5.10. Prospective

Measure 10.1. Define storage needs

Storage must meet the operational needs of the system on the basis of the scenarios provided for in the PNIEC, and in particular with regard to daily, weekly and seasonal flexibility.

In order to assess these needs and to define how storage can contribute to meeting them, different studies with different scopes will be carried out. These include

- Study on available flexibility resources (electric vehicles, thermal systems in buildings or demand management).
- Study on the impact of interactive (intelligent) buildings with thermal inertia on demand, flexibility they bring to the system, through thermal energy services (virtual storage systems), including commercial, residential and other buildings.

As part of these studies, indicators of various kinds will be defined, such as: technical indicators (useful life, response time, degree of reliability, power density, technology maturity, efficiency, number of cycles, among others), economic indicators, regulatory indicators, environmental indicators and social indicators.

Measure 10.2. Assess the cost-benefit of storage

The definition of a common methodology to identify and evaluate the costs and benefits of energy storage in its different applications will support decision-making on the use of one or another energy storage technology in different applications.

Action 10.3. Life cycle analysis: Environmental and social impact of mass storage

Carrying out a detailed analysis of the environmental and social impact of the massive implementation of storage systems throughout their life cycle by applying standardised tools.

Research and the use of new materials and critical materials leads to the use of products whose impacts are not fully known. Therefore, an assessment of the health and environmental impact of all the technologies developed is required in order to evaluate the risks inherent in them.

In addition to analysing each of the technologies individually, it will be necessary to look more closely at the impact of a massive implementation of storage systems. To this end, it is advisable to define sustainability indicators which include aspects such as recyclability index, indirect emissions, carbon footprint, use of materials, etc.

It is important to bear in mind that the final uses of the stored energy will largely determine the environmental goodness of each of the systems. To do this, it is necessary to compare each case with the conventional system for providing each of the energy uses considered, whether these are electricity, heat, mobility, fuels or chemicals.

On the other hand, it is essential to have a procedure for calculating the product's carbon footprint for storage technologies and solutions, from the beginning of their value chain to the end, so that they can be compared for their impact in a neutral way and the choice of one or the other can be assessed.

6. STORAGE OPPORTUNITIES

Achieving an effective energy transition and decarbonisation of the economy involves, among other aspects, the need to increase the electrification of the system and requires the integration of tools that provide flexibility to the electricity system in order to guarantee the stability of the network, minimise spills and maintain the security, quality and economy of supply. In this scenario, energy storage, in all its forms, plays a crucial role, and its deployment results in the emergence of multiple opportunities.

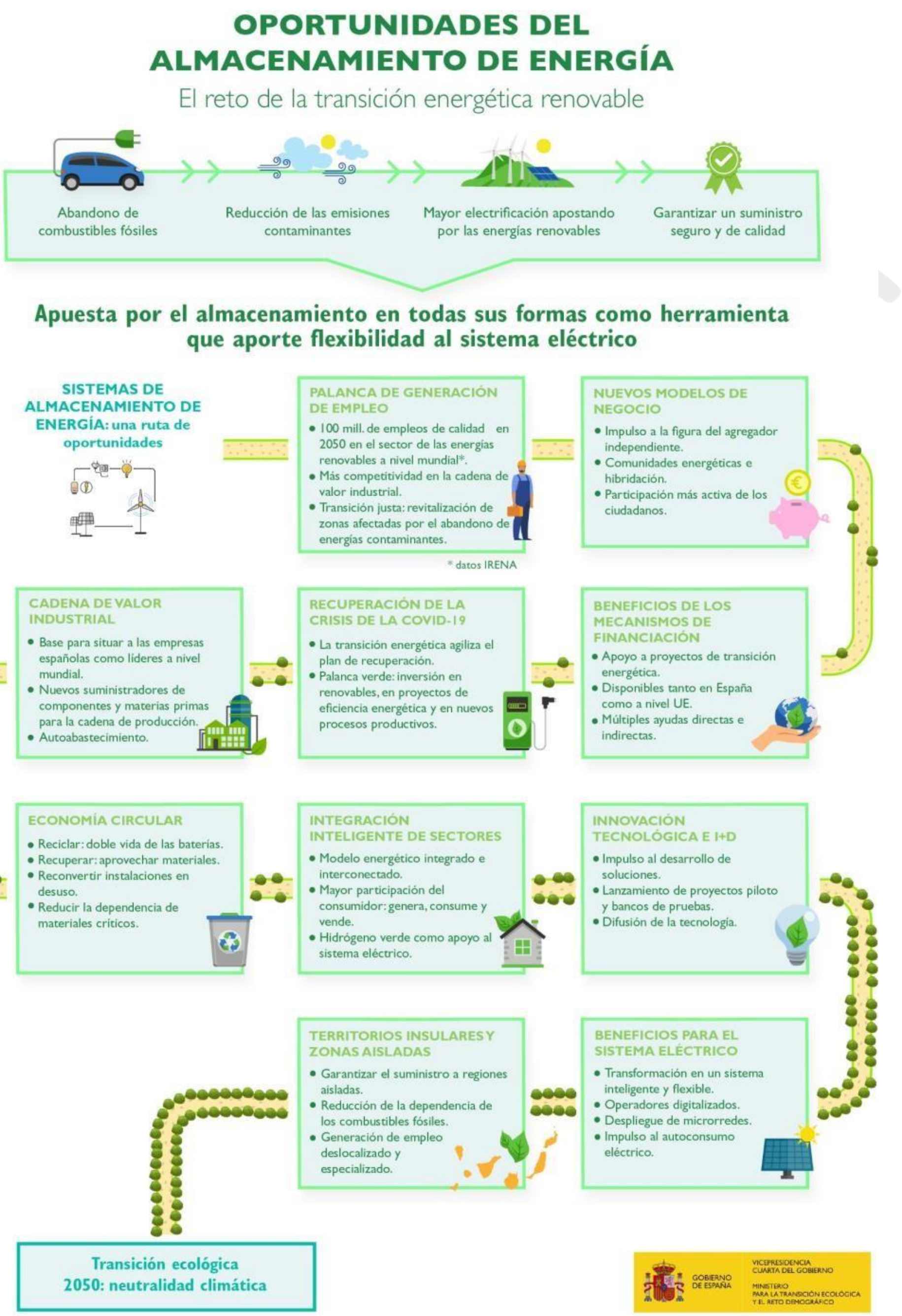

FIGURE 15. Energy storage opportunities

Lever for employment generation

In general terms, according to IRENA10 data, it is estimated that by 2050, 100 million jobs could be reached in the energy sector worldwide; some 40 million more than today. This includes up to 42 million jobs in the renewable energy sector, compared to just over 11 million in 2018. IRENA estimates that renewable energy and energy flexibility are more than 25 jobs per million dollars of investment.

Specifically, the deployment of storage systems has great potential as an instrument for generating quality employment, promoting innovation and competitiveness throughout the entire value chain, and reinforcing Spain's industrial leadership in this sector.

This results in other social benefits, such as gender equality, social inclusion, reduction of youth unemployment and equal opportunities, among others. In particular, the job creation fostered by this deployment, given its delocalised nature, will have a significant effect on regions that are economically dependent on fossil fuel-based technologies, mitigating the possible impact that could be caused by the abandonment of this type of technology to make way for other cleaner solutions, so necessary for the decarbonisation of the system. Consequently, energy storage represents an important opportunity for the adaptation of this process to a Just Transition.

Spain is already a leader in various storage technologies, including thermal storage, the result of the great development and level of maturity achieved in this technology in Spanish solar thermal plants, power electronics, conventional pumping stations or the most innovative Reversible Treatment Plants in old mines, among other technologies

New business models

The new paradigm derived from the energy transition implies the appearance and promotion of new business models thanks to the emergence of new figures such as independent aggregators, renewable energy communities, or hybridisation; figures for which storage will take on great relevance. Storage systems can be located at different points in the system, offering different value proposals. Furthermore, shared self-consumption and storage behind the meter will substantially modify energy management in buildings, which will become prosumers. Energy will be exchanged with the outside in a bi-directional way and will make the management of energy systems in buildings more complex, which will boost, and even make necessary, the management by Energy Service Companies (ESEs). Furthermore, these new possibilities in energy management will provide tools to improve energy efficiency.

The independent aggregator will offer new services to consumers and develop new business models based on the supply of services to the electricity system. This will be possible not only by aggregating large consumptions (such as those in the

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[10] IRENA (2020), The post-COVID recovery: An agenda for resilience, development and equality, International Renewable Energy Agency, Abu Dhabi

industrial), but that digitalisation will also allow equipment from a multitude of small consumers to be added, thus facilitating more active participation by consumers in the electricity system and enabling citizen participation in the new design of the electricity system.

Benefit from different financing mechanisms

There are, or are being developed, different financing mechanisms, both at European and national level, aimed at boosting the energy transition and the decarbonisation of the economy, for which projects related to energy storage would be eligible, given their importance in this process. These mechanisms include direct aid in the form of grants or loans on favourable terms, indirect aid, innovative public procurement, equity participation or financial guarantees, among others. Annex A to this document is devoted to a list of the various instruments available or under development.

Recovery from the COVID-19 crisis

The energy transition will be a key vector in the recovery from the impact of the international pandemic declared by the World Health Organization in March 2020. In response to this crisis, the decarbonisation agenda and the energy transition must be promoted and accelerated as a vector of economic recovery with new opportunities for local economies. Investments in renewable energies and their integration into the grid, energy efficiency and new production processes, with the economic activity and employment that these will bring, will act as a green lever for the recovery of the Spanish economy, contributing, moreover, to the fight against energy poverty.

Industrial value chain

It is necessary to take advantage of the momentum of the energy transition to strengthen the national industry around storage technologies and to promote the leadership of Spanish companies at international level. It is essential to have national manufacturers and suppliers that generate high added value throughout the entire industrial chain: from the supply of raw materials and basic components, where it is key to have a solid fabric of national suppliers that allows for the maximisation of self-supply, to the entire industrial chain, along which specialised industries will emerge that, through advanced manufacturing, will provide the necessary technology to deploy these systems.

Circular economy

The reinforcement of the value chain extends to the entire life cycle of technological solutions thanks to the boost of the circular economy. In this sense, opportunities of special relevance will arise around the second life of batteries, the recovery of materials and around new business models dedicated to closing the life cycle of systems, aimed at the recovery of waste from storage technologies.

This will reduce the existing dependence on so-called critical materials, while generating a business opportunity derived from their reuse and reducing the environmental impact produced by resource extraction.

On a larger scale, storage offers the opportunity to reconvert and reuse disused energy facilities that have been replaced by cleaner technologies, which are the result of the energy transition, thus reviving the economy in their environments.

Key role in the integration of sectors

In the transition from a linear energy model to a fully integrated and interconnected model, where the network of energy flows between producers and consumers in different sectors makes it possible to maximise the economic and energy efficiency of the system as a whole and to optimise its operation, storage has a key role to play, due to its cross-cutting nature to the different sectors and because it makes it possible to decouple generation and consumption.

In conjunction with storage systems, one of the great enablers of the full integration of sectors is green hydrogen, which, through the use of electrolysers, supports the operation of the electrical system, and plays a key role in the decarbonisation of industry.

Technological innovation and R&D

A change of paradigm such as the energy transition brings with it a strong boost to technological R&D and innovation, which are key in the search for the best solutions to enable this transition. In particular, the need to undertake pilot projects and test benches presents interesting opportunities both in terms of obtaining financing and in terms of creating regulatory sandboxes, which allow certain measures to be relaxed in order to provide flexibility in this sense. In addition, demonstration projects have a great role to play as dissemination tools. Changes in the model and the appearance of new technologies present acceptance curves which can be smoothed out thanks to this type of initiative.

Benefits for the electrical system

The deployment of storage solutions will bring significant benefits to the management of the electricity system. This extends beyond support to transmission, generation and distribution infrastructure. It also provides consistent support for the deployment of microgrids and has great potential as a mechanism to boost solar self-consumption. In this way, citizens will be given an important role, and will take an active part through this type of technology. In the same way, a more active role will be given to the operators of the distribution networks, which are increasingly digitalised and intelligent, where the storage behind the meter will acquire great relevance.

Island territories and isolated areas

Spain is a world leader in terms of the quality of its distribution networks. However, there are areas which, owing to their particular orographic features, are more isolated, which, together with the island territories, has traditionally been a challenge in the operation of the system. In these territories, storage offers enormous opportunities as an enabling technology for the decarbonisation of the system, reducing dependence on fossil fuels, in the case of island territories, and making the operation of distribution networks in isolated areas more flexible. In addition to this, there are other benefits, such as bringing delocalised and specialised employment closer to these regions.

7. POTENTIAL STORAGE NEEDS ON THE PATH TO CLIMATE NEUTRALITY

In the scenarios outlined in the PNIEC and the draft ELP, storage is one of the enablers for achieving climate neutrality. Among the technologies included in these scenarios are different forms of energy storage, with both large-scale and distributed applications.

The temporary scope of storage, i.e. the capacity of the different systems to conserve energy for use in the short, medium or long term, is also marked by different needs.

The figure shows the minimum storage needs foreseen for the temporary periods under consideration. It is estimated that the total storage capacity available in 2050 will increase from 8.3 GW at present to around 20 GW in 2030 and 30 GW in 2050.

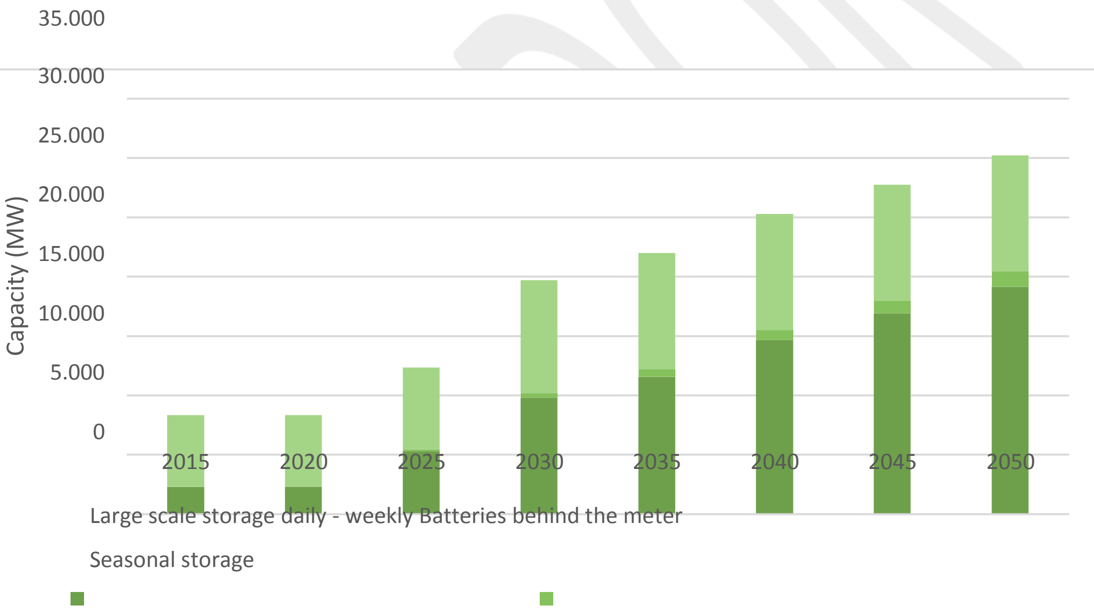

FIGURE 16. Forecast of storage needs

This quantification includes large scale daily and weekly storage, storage behind the meter and seasonal storage, according to the current state of technology, having considered different types of storage systems, including

- Hydraulic pumping systems.
- Batteries and other large scale storage systems
- Batteries behind the counter (for the year 2030 a minimum value of 400MW is included).
- Thermal energy storage, such as those used in solar thermal power plants.

With regard to other storage systems, the following observations are made:

- **Electric vehicle.** Non-stationary distributed storage using batteries with V2G technology. It is estimated that the electric vehicle fleet will provide around 26 GWh per year by 2030, which can be used to provide services to the electricity system. The storage capacity of the electric vehicle will not be fully available for all time periods due to the inherent limitations of electric vehicle use, so the total value of existing battery capacity would have to be increased by an availability factor dependent on vehicle use.
- **Seasonal storage systems**. For long-term decarbonisation, seasonal storage must be available by 2050 in order to have a 100% renewable electricity system. These seasonal systems, which have yet to be developed, have not been included in the above graph and will be studied as one of the works developed by the Strategy.
- There is potential in the **building sector** for thermal energy storage in various forms, whether through the use of storage tanks, building heaters, heat pumps coupled to storage tanks, or other heat and cold storage technologies.

In short, the wide range of storage solutions and technologies provide a wide variety of uses and applications, making it possible to combine intraday and seasonal storage and demand sharing, which is essential to guarantee security of supply and provide the flexibility that the energy system requires to achieve its decarbonisation.

ANNEXES:

ENERGY STORAGE STRATEGY

A. FINANCING MECHANISMS

One of the aspects considered in the process of defining the regulatory framework and participation in the markets in which energy storage activity will be confined is that this framework should be favourable to investment in this type of technology. However, these are capital-intensive projects and their viability may require additional support. This is why there are, or will soon be, numerous financing instruments, both at European and national level, aimed wholly or partly at promoting the development of energy storage projects and technologies, as one of the key elements in the energy transition and for the decarbonisation of the economy.

1. EUROPEAN INSTRUMENTS

In the framework of the European Union (EU) the main financial instruments with potential to support energy storage projects are

1. Next Generation EU and Recovery and Resilience Mechanism

Next Generation EU is a new instrument for recovery from the crisis caused by the COVID-19 pandemic, with a budget of EUR 750 billion, of which EUR 390 billion will be in the form of direct aid and EUR 360 billion in loans.

The central pillar of this instrument is the Recovery and Resilience Mechanism, which aims to promote the economic, social and territorial cohesion of the EU by improving the resilience of Member States, mitigating the social and economic impact of the crisis and supporting the green and digital transitions, thereby contributing to restoring the growth potential of EU economies, boosting job creation and sustainable growth.

The Facility will be endowed with EUR 672.5 billion to provide financial support for reforms and investments, of which EUR 312.5 billion will be provided in the form of grants and EUR 360 billion in the form of loans. Of the amount earmarked for grants, 70% is committed for the first two years, with the planned allocation for Spain being ?43.48 billion.

These funds will be able to finance energy storage projects as their objectives include support for the ecological transition to a climate-neutral economy, and this technology is essential to achieve a high penetration of renewable energies and the decarbonisation of the system.

In addition, *Next Generation EU* funds will be deployed through other new mechanisms or by reinforcing and increasing the funding of existing mechanisms, such as *InvestEU* or the Just Transition Fund, also listed in this Annex

More information:

https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1590732521013&uri=COM:2020:456:FIN

https://www.consilium.europa.eu/media/45124/210720-euco-final-conclusions-es.pdf

2. Innovation Fund

The *Innovation Fund* is one of the main funding programmes for innovative low carbon technology projects in the pre-commercial or commercial phase, one of which is energy storage. Five criteria will be applied in the selection process, in two stages: in the first stage, 1) emissions avoided, 2) the degree of innovation and 3) the state of maturity of the project will be assessed; in the second stage, 4) scalability and 5) cost efficiency will be evaluated.

In total, it is estimated that this Fund will manage around 10 billion euros in the period 2020-2030. The revenues come from the auctioning of allowances under the EU Emissions Trading Scheme (*EU ETS), as* well as from the remaining funds from the *NER300* programme.

The aid will take the form of subsidies of up to 60% of the additional costs linked to innovation, through annual calls for proposals. The first call was launched on 3 July 2020 and ends in October 2020. It is aimed at large-scale projects (CAPEX > 7.5 million euros) in eligible sectors, including energy storage, and is endowed with 1 billion euros, plus 8 million euros for project development assistance.

In addition, there will be a specific line for small-scale projects whose capital investment (CAPEX) is less than 7.5 million euros, which will be based on a shortened selection procedure in which the five criteria will be applied in a single stage, also using a more simplified valuation methodology. In this case, moreover, the 60% aid rate would be applied to the total CAPEX, instead of only to the additional costs arising from innovation.

More information: https://ec.europa.eu/clima/policies/innovation-fund_es

First call: https://ec.europa.eu/inea/en/innovation-fund/calls-proposal

3. Horizon 2020 and Horizon Europe

Horizon 2020 is the largest funding instrument for research and innovation at European level, with nearly 80 billion euros. Its objectives include supporting policies for the transition to a low-carbon economy, environmental protection and climate action. In general terms, around 35% of the programme is intended to finance research and innovation projects related to climate change, including those aimed at achieving clean, safe and efficient energy.

Currently the programme for the period 2018-2020 contributes to several focal areas, one of which is "*Building a low carbon and climate resilient future*", which is

3.4 billion, and has numerous calls for funding for projects that develop solutions to achieve climate neutrality and climate resilience in Europe in the second half of the century.

Horizon 2020 is the current EU Research and Innovation Framework Programme and was launched for the period 2014-2020. The next "*Horizon Europe*" Framework Programme is being developed for the period 2021-2027, which will be the successor to *Horizon 2020, and will be* endowed with 75.9 billion euros, of which an estimated 35% will be used to address the challenges of climate change, supporting policies for the transition to a low-carbon economy and environmental protection.

The new *Horizon Europe* incorporates as a novelty the concept of "missions" to improve the impact and visibility of research and development to the general public and society, by establishing ambitious, clear and measurable objectives, having defined five mission areas, including "*Intelligent and climate-neutral cities*". Achieving this mission objective will involve opportunities for different types of distributed storage.

The *Horizon Europe* programme will be structured around three main pillars, the first devoted to Excellent Science, the second to Global Challenges and European Industrial Competitiveness, and the third to European Innovation. Within the second pillar, six *clusters* have been defined. *Cluster* 5 is called Climate, Energy and Mobility, and in this *cluster* the funding opportunities for all the storage systems will be mainly collected. The new public-private partnership for batteries is located in this cluster, which is in the process of approving and defining its strategic research agenda, and which will be aligned with the work carried out in the framework of the European Technology Platform's working groups on batteries. This partnership will identify topics of interest to be financed through *cluster* 5 in certain areas of the battery value chain.

The *Horizon Europe* programme also incorporates, as a novelty, the concept of co-funding partnerships, which, among other aspects, will make it possible to give continuity to the well-known *H2020 Eranets,* which are transnational networks of public R&D&I funding bodies whose aim is to coordinate the national and regional research programmes of the Member States of the European Union and associated countries, as well as to prepare and implement joint calls to promote transnational research, technological development and innovation projects in strategic themes with high European added value. The countries also undertake to carry out additional activities of interest to them and their industrial and academic entities in a given area, in order to boost research, knowledge transfer and international cooperation towards the construction of the European Research Area (ERA).

The Centro para el Desarrollo Tecnológico Industrial (CDTI) and the Agencia Estatal de Investigación, have participated in many of the *Eranets* launched in *Horizon 2020,* as national funding agencies, and their participation in the new *co-funding* instruments for the *Horizon Europe* period is under study. In this sense, within *cluster* 5, two *co-fund* instruments are in the preparation and approval phase, one focused on energy transition and another to the urban transition (cities). Both will generate opportunities for transnational projects, among others, in the storage sector. The specific terms of *Horizon Europe are* still being negotiated and the first calls are expected to be launched in early 2021.

More information:

- Horizon 2020: https://ec.europa.eu/programmes/horizon2020/en
- Horizon Europe: https://ec.europa.eu/info/horizon-europe-next-research-and-innovation-framework-programme_en

4. *European* Green *Deal*

The *European Green Deal* call is part of the *Horizon 2020* programme, and has recently been launched (the deadline for submission of proposals is 22 September 2020 to 26 January 2021). The call for proposals has a budget of 1 billion euros and is made up of ten areas (eight of which are thematic and two cross-cutting), including: "Clean, safe and affordable energy", "Industry for a circular and clean economy", "Resource and energy efficient buildings" and "Intelligent and sustainable mobility". The aim of the call is to mobilise research and innovation to respond to the climate crisis and help protect Europe's ecosystems and biodiversity.

Más información:
https://ec.europa.eu/info/sites/info/files/research_and_innovation/green_deal/ec_rtd_factsheet-green-deal-call.pdf

5. Implementation Act on the European Union Renewable Energy Financing Mechanism

Article 33 of Regulation (EU) 2018/1999 on the governance of the Union for Energy and Climate Action provides that the European Commission shall establish by 1 January 2021, by means of an implementing act, the Union's renewable energy financing mechanism. The content of this implementing act has already been negotiated between member states, the vote took place in the second half of July 2020, and publication in the OJEU is planned for the last quarter of 2020.

This mechanism will have two purposes: on the one hand, it will support new renewable energy projects with the aim of closing a gap in the Union's indicative trajectory. To this end, Member States will be able to make a voluntary financial contribution to the financing mechanism, with part of the energy generated in the installations being subsequently counted towards its objectives, regardless of where the installations are physically located. Furthermore, the financing mechanism will contribute to the enabling framework for renewable energy as defined in Article 3(5) of Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources, with the aim of supporting an ambitious deployment of renewable energy in the Union.

As part of the support for the renewable energy enabling framework, which may be funded by both Member States and the Union itself, the implementing act provides that, among others, renewable grid integration projects may be developed, and it explicitly states in its preamble that energy storage may be eligible, provided that it is accompanied by new renewable generation capacity.

The way in which financial resources will be made available to projects will be through calls for proposals organised directly by the Commission or one of its agencies. The most likely mechanism for allocation will be through auctions, with the option of a price allocation (*pay-as-bid, pay-as-clear,* etc.) defined in each call. The implementing act provides for annual calls for proposals, provided that funds are available from both the Member States and the Union itself. The mechanism is open to cooperation projects with third countries outside the EU.

6. InvestEU

The *InvestEU* programme is an EU instrument which aims to mobilise public and private funding for strategic investments in the framework of European policies. It will cover the period 2021-2027 and will bring together under one umbrella the European Strategic Investment Fund and 13 other existing EU financial instruments. It is expected to generate additional investment of at least ?650 billion.

The *InvestEU* fund aims to mobilise public and private investment by providing an EU budget guarantee to financial partners such as the European Investment Bank Group (EIB Group), strengthening their risk absorption capacity.

Más información: https://ec.europa.eu/commission/priorities/jobs-growth-and-investment/investment-plan-europe-juncker-plan/whats-next-investeu-programme-2021-2027_en#documents

7. Just Transition Fund

This facility will be endowed with EUR 7.5 billion from the growth and jobs objective and an additional EUR 10 billion from the Recovery and Resilience Mechanism. The Fund is designed to support the transition of the regions most affected by the need to move away from a fossil fuel-based economic model and therefore targets regions that are more carbon-intensive or more dependent on fossil fuels. The eligibility criteria and the typology of the projects to be financed are still under discussion, but it is expected that certain coal-related regions in Spain may become eligible, with energy storage and renewable generation being a possible solution for the economy and employment of these regions.

More information:
https://www.europarl.europa.eu/RegData/etudes/STUD/2020/651444/IPOL_STU(2020)651444_EN.pdf

8. European Regional Development Fund (ERDF)

The ERDF aims to strengthen socio-economic cohesion within the EU by correcting imbalances between its regions. In the period 2014-2020 this Fund has had a particular impact on four thematic areas: Research, Development and Innovation; Programme

digital and information and communication technologies; support for SMEs and the low-carbon economy In Spain, the lines of aid in this last thematic area, whose main objective is to favour the transition to a low-carbon economy, are managed by the Institute for Energy Diversification and Saving (IDAE). Within this framework, the IDAE has launched numerous aid programmes for energy saving and efficiency and renewable energy projects, either in the form of grants or low interest loans.
For the next EU budget period, at least 30% should be dedicated to the political objective of "greening Europe" by implementing the Paris Agreement and investing in energy transition, renewable energy and climate action, where energy storage is expected to have a large share.

More information: https://ec.europa.eu/regional_policy/es/funding/erdf/

9. InnovFin Energy Demonstration Projects

InnovFin Energy Demonstration Projects is a European Investment Bank financing facility, consisting of loans, loan guarantees or equity financing of between EUR 7.5 and 75 million, for innovative projects in the field of energy system transformation, including renewable energy and energy storage technologies, which aim to reduce the gap between demonstration and commercialisation.

For a project to be eligible for *InnovFin Energy Demonstration Projects it* must contribute to the energy transition, particularly in the fields of renewable energies, intelligent energy systems, energy storage and carbon capture; it must be innovative, replicable, in a demonstration phase close to the pre-commercial level, and attractive to investment. For their part, the promoters must be prepared to co-finance the project in a significant way.

More information:
https://www.eib.org/en/products/blending/innovfin/products/energy- demo-projects.htm

10. Connecting Europe Facility (CEF)

EFC is a financing instrument to promote the development of infrastructure for interconnected, high-performance, efficient and sustainable trans-European networks in the fields of transport, energy and digital services. In particular, in the energy sector, this funding mechanism is directly linked to the Projects of Common Interest of the European Union (PCIEs), so that these projects are eligible for this funding mechanism.

The EFC's planned budget allocation for 2021-2027 is ?28.396 billion, of which 60% is expected to be used to meet climate objectives. The funds will be distributed among the three sectors, with 21,384 million euros allocated to the transport sector, 5,180 million euros to the energy sector and 1,832 million euros to the digital sector. The energy sector call is expected to be held throughout 2021.

More information: https://ec.europa.eu/inea/en/connecting-europe-facility

11. European Strategic Investment Fund (ESSF)

The EIF functions as a guarantee of the EU budget, providing the EIB Group with protection against first loss. This means that the EIB Group can provide financing for projects with a higher risk than it would normally take. An independent Investment Committee applies strict criteria to decide whether a project is eligible for EIF assistance. There are no quotas, either per sector or per country. Funding is granted on a demand-driven basis only.

The EIF aims to overcome current market failures, address market gaps and mobilise private investment. It helps finance strategic investments in key areas such as infrastructure, research and innovation, education, renewable energy and energy efficiency, as well as risk financing for SMEs.

From 2021, the EIF will be integrated into *InvestEU.*

Más información: https://ec.europa.eu/commission/priorities/jobs-growth-and-investment/investment-plan-europe-juncker-plan/european-fund-strategic-investments-efsi_es

12. European Battery Alliance (EBA250)

The EBA250 was established in October 2017 as a set of actions aimed at achieving a European battery development and production industry that is competitive, innovative and sustainable throughout the value chain. Although it is not a financing mechanism in itself, its interest lies, among other aspects, in the fact that, within the framework of the EBA250, a European technological innovation platform has been created (*ETIP-European Technological Innovation Platform) in batteries,* called *ETIP-BATTERIES EUROPE,* which is the framework for collaboration, or *marketplace,* between all the different European *stakeholders in the* area of batteries, covering the entire value chain of research and innovation in this sector. The European Alliance of Batteries brings together the European Commission, the interested Member States, the European Investment Bank and the industry.

It is estimated that the market generated will reach an annual value of ?250 million by 2025, generating an industrial fabric that combines the most innovative European skills, financial capacity and an approach covering the entire industrial value chain.

The Alliance is managed by *EIT InnoEnergy, through* its Knowledge and Innovation Community (*Kic - InnoEnergy)* integrated into the *European Institute of Innovation and Technology* (*EIT), a* European Union body aimed at strengthening European innovation capabilities.

More information: https://www.eba250.com/

13. Eurostars Programme

Eurostars is a programme to support R&D-intensive SMEs in the development of market-oriented transnational projects. This initiative is based on Article 185 of the Treaty of

Functioning of the EU concerning the participation of the EU in joint research and development programmes

It currently involves 25 *EUREKA* Member States and the EU, in strong support of innovative European SMEs. Up to 2020 the EU will provide ?287 million from the *Horizon 2020* SME facility, to which will be added more than ?800 million from the signatory countries.

In Spain, the Ministry of Science and Innovation, through the CDTI, is responsible for managing the programme.

More information: https://www.eurostars-eureka.eu/

14. European Social Fund + (ESF+)

The European Social Fund +, ESF+, is one of the funds of the Cohesion Policy and the main instrument with which Europe supports job creation, with training and capacity building being the main mechanisms. Thus, it is possible to finance with ESF+ (ESF for the period 2021-2027) the initiatives or training programmes needed to promote energy storage.

The fund would serve to meet the social and environmental challenges mentioned in this Strategy since one of the challenges is to have adequate training for professionals in the industrial and energy sectors at all stages of the value chain. It could also finance the implementation of measures related to the adaptation of training and curricula and the qualification and certification of installers in the residential sector.

More information: https://ec.europa.eu/esf/home.jsp?langId=es

	Description and characteristics	**Equipment**	**Type of aid**	**Calls for proposals**
Next Generation EU	• New instrument for recovery from the COVID-19 crisis. • Recovery and Resilience Mechanism is its main instrument • Among its objectives is support for ecological transition.	NGEU: 750,000 M€ MRO: 672,500	Grants and loans	---
Innovation fund	• One of the main financing programmes for innovative low-carbon technologies. • Specific storage line. • Selection criteria: 1) Avoided emissions 2) Degree of innovation 3) Project maturity 4) Scalability 5) Cost efficiency • Annual calls. • Specific line for projects with CAPEX < 7.5M	10.000 M€	Subsidy. Up to 60% of additional costs derived from innovation	July 2020. 1000 M€
H2020	• The largest European funding instrument for R&D&I • Among its objectives are: ○ The transition to a low-carbon economy ○ Protection of the environment ○ Climate action.	80.000 M€. The 2018-2020 programme 3.4 billion for the climate.	Miscellaneous	Miscellaneous

	• Currently the priority area is: "Building a *low carbon and climate friendly future resilient*".			
Horizon Europe	• The next framework programme to succeed H2020. • Currently under development • *Cluster* for *Climate, Energy and Mobility* • It will incorporate *co-funding* partnerships	Under negotiation. Estimated 75.900M euros, 35% for change climate.	Miscellaneous	January 2021
European Green Deal	11 areas, among them: • Clean, safe and affordable energy • Industry for a circular and clean economy • Resource and energy efficient buildings • Intelligent and sustainable mobility	1.000 M€	Miscellaneous	September 2020
Implementing act on the Union's financial mechanism	• A support mechanism at Community level, which aims to ensure that certain MEGs achieve their renewables targets and to encourage the ambitious development of renewables in the EU. • Storage is contemplated (as long as it is associated with a new renewable generation). • Selection criteria: ○ Price, in the case of auctions associated with the *gap-filling* function of the targets. ○ To be determined in each call, in the case of of the enabling framework.	Not determined	In the case of *gap filling,* the only awarding criterion in the auction will be the price. In the case of the facilitating framework, this will be determined in each call for tenders.	The first call is scheduled for 2021. If funds are available, annual calls will be made.
InvestEU	It aims to mobilise public and private investment by providing guarantees to financial partners such as the EIB Group.	2.8 billion + instrument flows previous	Financial guarantee	2021
Just Transition Fund	Aimed at supporting the transition of the regions most affected by the need to move away from an economic model based on fossil fuels	7.500 M€	Grants	2021
ERDF	• Objective: to correct imbalances between regions. • It focuses its investments on four thematic areas, one of which is the economy of low carbon emissions.	---	Grants or loans	Various
InnovFin	• Financing of innovative projects for the transformation of the energy system. Includes renewable energies and storage. • Objective: to reduce the gap between demonstration and marketing.	Financing between 7.5 and 75 million euros.	• Loans • Loan guarantees • Share capital participation	Miscellaneous
CEF	IPCEI are eligible for this funding mechanism.	43.000 M€. 60% for climate. 9,000 million for energy.	---	2021
EIF	Support for strategic investments in key areas, including clean energy.	---	Financial guarantee	In 2021 integrated in InvestEU
European Battery Alliance EBA250	• Marketplace that brings together different agents in the battery industry and investors. • Objective: to achieve a competitive and sustainable European battery industry throughout the value chain	---	---	---
Eurostars	• Programme to support R&D-intensive SMEs in the development of market-oriented transnational projects	287M euros of H2020 + 800M euros of party countries	---	Miscellaneous
ESF+	Support for job creation, with training and capacity building being the main mechanisms.	---	Grants or loans	Miscellaneous

2. NATIONAL INSTRUMENTS

1. Green bonds

In recent months, building on the momentum of the Green Pact, a number of initiatives have been launched in this area. One of them is aimed at encouraging the development of "green bond" markets for public and private financing. Green bonds are fixed-income instruments whose principal is issued to finance or refinance environmental investment projects.

Spain could benefit from the boom in the sustainable finance market by diversifying its investment base, especially in Europe where most sustainable investors are concentrated. In addition, given the market's appetite for such bonds, the green bond issue could provide a slight cost advantage. It could also generate positive externalities for the corporate green bond market in Spain by establishing a baseline for the market.

2. R&D&I support instruments managed by CDTI

The Centro para el Desarrollo Tecnológico Industrial (CDTI) is the agent managing the aids from the General State Administration for business R&D&I. To this end, the CDTI manages the various aid programmes, applicable according to the project's level of maturity and proximity to the market. Below is a list of the different instruments for which projects related to storage could be eligible.

2.1. Aid for R&D

Between 2017 and 2020, CDTI has contributed around 30 million euros in the form of aid to R&D related to storage. This aid is organised through two mechanisms: partially reimbursable aid and subsidies.

- **Partially reimbursable aid:**
  - **CDTI R&D Projects:**
    Project categories:
    - **CIEN Projects:** large R&D projects, developed in effective collaboration by business groups and aimed at carrying out planned research in strategic areas of the future and with potential international projection.
    - **R&D projects:** developed by companies and aimed at creating and significantly improving production processes, products or services.

    Call for applications: open all year round.
    Characteristics of the aid: Financing of up to 85% of the budget by means of a loan at a fixed interest rate (1-year Euribor), to be paid back in between 7 and 10 years, with a grace period of between 2 and 3 years. Non-refundable instalment: 33%. **More information:** https://www.cdti.es/index.asp?MP=100&MS=802&MN=2

  - **Cervera Transfer Projects**

Purpose: Aid for individual R&D projects carried out by companies collaborating with state-run Technology Centres in Cervera's priority technologies, including: hybrid generation, storage and hydrogen systems.

Call for applications: open all year round.

Characteristics of the aid: Financing of up to 85% of the budget by means of a loan at a fixed interest rate (1-year Euribor), to be paid back in between 7 and 10 years, with a grace period of between 2 and 3 years. Non-refundable instalment: 33%. **More information:** https://www.cdti.es/index.asp?MP=100&MS=881&MN=2

- **Subsidies:**
  - **Science and Innovation Missions.** The programme finances large strategic initiatives, intensive in Industrial Research, that incorporate the most recent scientific-technical trends, developments and challenges in order to identify and solve the challenges faced, in the future, by critical productive sectors for the Spanish economy and for the generation of employment. It has 5 priority lines or "missions", among which are "Safe, efficient and clean energy for the 21st century" and "Sustainable and intelligent mobility". **Calls for proposals.** Annual. The last one ended in July 2020.

    Equipment. The last call was for 95 million euros.

    More information:
    https://www.cdti.es/index.asp?MP=100&MS=902&MN=2&TR=C&IDR=2902&r=1252*783

2.2. Innovative public procurement

This is the acquisition by the CDTI of prototypes of first products or services in the pre-commercial phase, in the form of test series, technologically innovative and meeting public needs. The prototype that is developed, if any, will be given to the Spanish Public Administration that is interested in it and can provide the real environment necessary to validate the proposed technology. The prototype must be used exclusively to validate technology, with no subsequent commercial purpose.

More information: https://www.cdti.es/index.asp?MP=100&MS=882&MN=2

2.3. WINTER

Co-investment programme with private investors in specialised capital whose objective is to stimulate investment in Spanish technological and innovative companies.

More information: https://www.cdti.es/index.asp?MP=100&MS=819&MN=2

2.4. Aid for innovation

Support for projects of an applied nature, very close to the market, with medium/low technological risk and short periods of investment recovery, which manage to improve the competitiveness of the company through the incorporation of emerging technologies.

Call for applications: all year round

Characteristics of the aid: The innovation hotline is partially reimbursable aid in the form of a loan over 75% of the budget. The interest rate depends on the repayment period: for 3-year repayments, Euribor + 0.2% and for 5-year repayments, Euribor + 1.2%. Non-repayable instalment: 2% as a general rule and 5% if co-financed by the ERDF.

More information: https://www.cdti.es/index.asp?MP=100&MS=812&MN=2

3. IDAE MANAGED SUPPORT INSTRUMENTS WHICH MAY INCLUDE STORAGE SYSTEMS

3.1. Aid for investment in electrical or thermal energy generation facilities using renewable energy sources, eligible for co-financing from European Union funds

The Institute for Energy Diversification and Saving (IDAE) is currently developing an aid programme aimed at promoting the development of innovative projects throughout the country that meet the new requirements of the European Directives for the integration of renewable energies into the electricity network. In this sense, the development of projects is not only based on the promotion of a specific renewable technology, but also on the adaptation of the different technologies to each other (which may include investment actions to improve management and optimise production through, for example, storage technologies) and with innovative demand management systems, such as renewable energy communities and collective financing of projects. Furthermore, this aid can also contribute to the economic development and social cohesion of those territories particularly affected by the Energy Transition.

For the purposes of these calls for aid, various storage systems are considered (hydraulic, batteries, hydrogen, heat/cold storage, phase changes, molten salts, thermal storage in the subsoil or in aquifers, etc.), associated with different renewable technologies, both electrical (hydraulic, photovoltaic, wind) and thermal (biomass, concentrated solar power, geothermal). The type of technology and associated storage varies depending on the Autonomous Community in question. Since these aids are currently being defined, they are likely to vary or include other types of storage systems or technologies than those previously described.

The aid will take the form of subsidies covering between 10% and 80% of eligible costs, depending on the action, through calls for proposals in each of the Autonomous Communities concerned, with the total budget estimated at ?316 million, although some of this will be for existing programmes in non-peninsular territories focusing on wind and solar photovoltaic energy. Orders TED/766/2020 and TED/765/2020, of 3 August 2020, establish the regulatory bases and the first calls for proposals under these orders will start in September 2020, having been developed specifically for each Autonomous Community through bilateral working groups with the IDAE.

More information: http://www.idae.es

3.2. SolCan 2020. Aid for investment in photovoltaic solar technology electricity production facilities in the Canary Islands

The first call for aid for investment in photovoltaic solar technology electricity production installations in the Canary Islands, co-financed by Community ERDF funds, was authorised by the Council of Ministers on 23 June 2020, on a proposal from the Ministry for Ecological Transition and the Demographic Challenge. The bases are set out in Ministerial Order TEC/1380/2018 of 20 December establishing the regulatory bases for the granting of aid for investment in installations for the production of electricity using wind and photovoltaic technology located in the non-mainland territories co-financed by Community ERDF funds, and the SolCan call was launched by Resolution of 24 June 2020 of the Directorate-General of the Institute for Energy Diversification and Saving, establishing the first call for aid for investment in photovoltaic solar technology electricity production facilities located in the Canary Islands, co-financed by Community ERDF funds. (Extract published in the BOE (Official State Gazette) No. 182 of 2 July 2020)

The call is aimed at construction and start-up activities of electricity generation facilities from photovoltaic solar technology with nominal installed power of inverter or inverters working in parallel for the same owner over 100 kW, located in the Canary Islands. The installations must be connected to the distribution and/or transport network, self-consumption installations are considered and energy storage is rewarded.

4. R&D AID INSTRUMENTS MANAGED BY THE SPANISH RESEARCH AGENCY (AEI)

The State Research Agency is an instrument for the financing of R&D&I activities with public funds. Its purpose is to promote scientific and technical research in all areas of knowledge through the efficient allocation of public resources, to encourage collaboration between the agents in the R&D&I system and to support the generation of knowledge with a high scientific and technical, economic and social impact, including that oriented towards the challenges of society and the monitoring of the activities financed.

The State Plan is the main instrument of the General State Administration for the development and achievement of the objectives of the Spanish Strategy for Science and Technology and Innovation and includes state aid for R&D&I, which is granted preferably through competitive calls for proposals.

More information: https://www.ciencia.gob.es/portal/site/MICINN/aei

Summary table

	Description and characteristics	Equipment	Type of aid	Calls for proposals
IDAE aid programme for innovative renewable electricity generation	• Storage is considered if it is associated with new renewable generation. • Selection criteria: 1) Economic criterion 2) Just Transition Zone 3) Administrative feasibility 4) Positive externalities • Specific calls and by Autonomous Regions. • Participation in local markets and renewable energy communities will be valued positively	316 M€	Subsidies of up to 80% of eligible costs depending on autonomous community action	September 2020
SolCan 2020	• Construction and start-up of electrical energy generation facilities using photovoltaic solar technology in the Canary Islands. • Storage is rewarded	20 M€	Grant	July 2020
R&D support instruments managed by the AEI	• Public funding of R&D&I activities	---	Grant	New State Plan (December 2020)

B. PUBLIC PARTICIPATION

The development of the Energy Storage Strategy has been supported by an important public participation process, giving the different agents involved the opportunity to contribute to its development. Prior to its preparation, bilateral meetings were held with numerous organisations related to energy, the electricity sector and storage. In addition, a prior public consultation was carried out for the free contribution of all those interested in contributing, the details of which are set out below. During the analysis of this prior public consultation, a stakeholder consultation was carried out, channelled through five thematic days, also described in this annex. The contributions from both consultations were analysed and, where appropriate, incorporated into the drafting of the Strategy.

After the drafting of the Strategy, it will be submitted for further consultation and comment by the various organisations involved and the general public.

1. Prior public consultation

Between 8 April and 19 June 2020, the public consultation process for the preparation of the Energy Storage Strategy was carried out simultaneously with that for the preparation of the Hydrogen Roadmap, with the aim of taking advantage of the possible synergies between the two. The consultation was carried out through the Public Participation section of the Ministry of Ecological Transition and Demographic Challenge website, asking participants to answer 14 questions published in that section.

Eighty-six entities participated in the consultation process, most of them companies and business associations, mainly linked to the energy, industry and transport sectors. In addition, public administrations, mostly local councils, entities linked to R&D&I, and private individuals also participated.

From the responses to the consultation, there is a broad consensus on the need for storage as an element favouring energy transition, on the flexibility it brings to the system, and on its great potential for the development of national industry and the generation of employment.

In relation to the aspects that, according to the participants, the strategy should include, the responses to the consultation focus on the need for a clear definition of the regulatory framework, so as to reduce the uncertainties relating to the figure of storage, as well as the establishment of a regulatory framework that avoids duplication of charges and double taxation, these two aspects being identified as one of the greatest challenges to be faced, together with that of favouring the creation of flexible and competitive markets that encourage investment in this type of technology. In this sense, it is urged that the new regulatory framework welcomes the different business models that may arise, derived from the opportunities provided by the energy transition.

One of the main concerns expressed by the industry is related to market participation, and in particular how to cover the costs of storage technologies in cases where they are not recovered through market participation.

In addition, the strategy should define specific objectives and quantify storage needs, based on the scenarios set out in the PNIEC and the large deployment of renewables which it envisages.

With regard to the different storage technologies, it is stressed that the strategy should focus on regulation that favours technological neutrality, so that all technologies compete on a level playing field.

One of the most pointed out opportunities is that of strengthening national industry along the entire value chain, boosting the circular economy. In this sense, special emphasis is placed on R&D&I as a key tool for positioning Spain as a leader in storage technologies.

Finally, another of the great challenges identified is that of achieving broad citizen participation, which is achieved by promoting self-consumption, electrical mobility, and the implementation of demand management systems.

In any case, the main conclusion of the analysis of the contributions to the prior public consultation is that it is crucial to define a regulatory framework that serves as a basis and favours the development of storage activity, which is so necessary for the decarbonisation of our country's energy system.

2. Stakeholder consultation

The consultation of the actors involved was organised over five days in which specific topics related to storage were discussed, through presentations by highly prestigious organisations and agents in the sector, followed by a space open to debate by all those attending.

The conference took place in weekly three-hour sessions between 19 June and 14 July 2020. As a particularity, due to the pandemic outbreak of Covid-19 and the impediments derived from it, in relation to the holding of meetings in person, the five sessions were held telematically, which in no way hindered dialogue.

The conferences, whose agendas are detailed at the end of this appendix, dealt with the following topics, all of them related to the role of storage in a decarbonised and flexible energy system:

Large scale storage (in front of the meter) 2. Distributed
storage
3.- Technological development challenges for storage (R&D&I) 4.-
Intelligent integration of sectors

5.- Cross-cutting issues.

All the sessions had a high participation, bringing together more than 60 attendees per session, and reaching nearly 80 in some of them. Representatives from various fields related to storage were invited to participate, including companies from the sector representing the entire value chain, the European Commission, business associations, academic and scientific-technological bodies, professional associations, public administrations, consultancies, cooperatives and social organisations, among other agents.

For the presentations, details of which are given later in this document, actors were chosen who would provide great added value to the presentations, derived from their experience and knowledge, either in the storage industry specifically, or in more general aspects related to this technology (regulation, electricity sector, R&D&I, hydrogen, environment, etc.).

The presentations were followed by a space for dialogue for the free intervention of the different participants, where they could set out their vision on the subject and make the contributions they considered appropriate, with the aim of contributing to the development of the Energy Storage Strategy.

The initiative aroused great interest and was very well received. Following the sessions, many proposals for collaboration in the development of the strategy were received, as well as requests for the material covered in the presentations and many congratulations on the initiative, the quality of the presentations and the opportunities for dialogue and collaboration that have arisen as a result.

In total, more than 30 presentations were made, to which were added numerous interventions and reflections by the rest of the attendees. Details of the different sessions are given below.

2.1. Details of the development of the sessions

<u>Session 1: Large scale storage (in front of the meter)</u>

The first session, held on 19 June 2020, focused on energy storage in front of the meter. It was moderated by the Subdirectorate General for Energy Forecasting, Strategy and Regulation of the Ministry of Ecological Transition and the Demographic Challenge. It included presentations by the European Commission, which presented its study on Energy Storage; Red Eléctrica de España (REE), which explained the benefits that storage will bring to the electricity system, in terms of its operation, flexibility and reliability; the National Commission for Markets and Competition (CNMC), which dealt with the different regulatory issues of energy storage; OMIE (Operador del Mercado Ibérico - Polo Español), which dealt with aspects relating to the participation of storage in the markets; and finally AEPIBAL, the business association for batteries and energy storage, which provided its vision of the sector.

Session 2: Distributed storage

The second day took place on 26 June 2020 and dealt with storage behind the meter. It was moderated by the Institute for Energy Diversification and Saving (IDAE) and included presentations by different organisations related to the subject.

Acciona Esco, a company of the Acciona group dedicated to the provision and management of energy services, focused its presentation on the role of storage in offering this type of service. AEDIVE (Business Association for the Development and Promotion of the Electric Vehicle) analysed the potential of electric vehicles as a tool to provide flexibility to the electricity system through the use of their batteries. Aelec (Association of Electrical Energy Companies) provided an overview from the perspective of electrical companies, focusing on opportunities for storage and regulatory and technological aspects, among others. Ampere Energy, a company that offers services related to self-consumption and intelligent energy management, focused its presentation on the role of storage in self-consumption and *virtual power plants* (VPP). APPA Renovables, an association of renewable companies, discussed energy communities and VPPs, describing successful cases. Finally, AEE (Asociación Empresarial Eólica) dealt with energy storage in wind generation.

Session 3: Technological development challenges for storage (R&D&I)

The third session, held on 2 July 2020, dealt with the challenges and opportunities of storage in terms of technological R&D&I. The session was moderated by the General Secretariat for Innovation, of the Ministry of Science and Innovation. The presentations were given by different technology platforms and centres that have projects related to storage.

BatteryPlat, a Spanish technological platform for energy storage, made up of multiple organisations, dealt with various technological aspects of batteries. Ciemat carried out an analysis of the technological challenges of storage by technology and by sector and presented the strategic lines of R&D&I in storage at Ciemat. The National Hydrogen Centre focused its presentation on the potential and technology related to this energy vector. Tecnalia, Spain's leading technology centre in applied research and technological development, provided an overview of the challenges of R&D&I in storage, highlighting the importance of developing demonstration projects.

The Centro para el Desarrollo Tecnológico Industrial (CDTI) provided information on the different financing mechanisms available to the promoters of this type of project. Ciuden (Ciudad de la Energía), a platform for the development of energy management technologies, including storage technologies, described, in addition to its projects, various European initiatives related to technological R&D&I in the field of storage. The University of Lleida focused its presentation on thermal storage and presented the Spanish thermal storage network, which is made up of several universities.

Finally, CIC energiGUNE, a technology centre for electrochemical energy and thermal storage, presented its different lines of research located along the entire value chain, described European benchmark initiatives and proposed a series of recommendations to be considered in the development of the strategy, from the point of view of its scope of work.

Session 4: Smart integration of sectors

The fourth day was moderated by the Subdirectorate General for Hydrocarbons and New Fuels, of the Ministry for Ecological Transition and the Demographic Challenge. It was held on 9 July 2020, one day after the publication by the European Commission of the European Strategy for the Integration of the Energy System and the European Hydrogen Strategy, and the session was attended by a member of the Commission who presented both strategies.

This was followed by presentations related to sectoral integration by organisations from different sectors. Protermosolar, the Spanish Association for the Promotion of the Thermosolar Industry, addressed the potential of this technology, in which Spain is a leader, in the integration of sectors through energy storage. Enagás, the natural gas transport company and Technical Manager of the Spanish Gas System, addressed the opportunity represented by the use of gas networks for effective sector integration, as well as the potential for using renewable gases as an energy vector. Along these lines, the Spanish Hydrogen Association (AeH2) focused on the potential of green hydrogen, describing, among other aspects, various European initiatives set up to promote it.

The Spanish Association of Oil Product Operators presented the possibilities that Spain has in terms of the production of eco-fuels, renewable gases and green hydrogen, through its refineries, among other infrastructures. Finally, IMDEA focused on storage as a nucleus of interconnection between the different sectors, reviewing different enabling technologies for the integration of sectors through energy, illustrating its potential through an example of an integrating project in which this organisation participates.

Session 5: Cross-cutting issues

The fifth session dealt with cross-cutting issues related to storage such as sustainability, new business models, alternative business models, and just transition, among others. Held on 14 July 2020, and moderated by the Subdirectorate General for Energy Forecasting, Strategy and Regulation.

In this session, Greenpeace contributed its vision on the importance of storage for the decarbonisation of the system, focusing on the environmental aspects of this type of project. RESCoop Eu, the European Federation of Renewable Energy Cooperatives, described the role of these entities in the energy sector, while Unión Renovables, the Union of Consumer and User Cooperatives for Renewable Energy, complemented this vision with its presentation along the same lines.

BeePlanet, a company dedicated to the integral management of second life batteries, described their business model consisting of the recovery and re-commissioning of this equipment.

Sarga, an instrumental society of the Regional Ministry of Rural and Sustainable Development which develops various projects aimed at improving the rural environment and the region's environment, and which has participated in a pilot project for self-consumption and storage under the transnational *Interreg Med programme, a* programme aimed at the sustainable development of Mediterranean countries through innovative projects, described its experience during that project.

Finally, R2M Solutions, a company specialized in offering innovative solutions in different areas, addressed the business opportunities arising from the creation of energy communities.

2.2. Session agendas

1ST SESSION. LARGE SCALE STORAGE (IN FRONT OF THE METER)	
SCHEDULE:	**ACTIVITY**
10:00-10:05	Opening of the Session and Introduction
10:05-11:00	Presentations by speakers and questions Moderator: Subdirectorate General for Energy Prospects, Strategy and Regulations (Ministry for Ecological Transition and the Demographic Challenge):
	EUROPEAN COMMISSION
	SPANISH ELECTRICITY NETWORK
	CNMC
	IMOE
	AEPIBAL
11:00-11:35	Questions and reflections from the audience
11:35-11:55	Rest
11:55-12:55	Questions and reflections from the audience
12:55-13:00	Close

2ND SESSION. DISTRIBUTED STORAGE (BEHIND THE METER)	
SCHEDULE:	**ACTIVITY**
10:00-10:05	Opening of the Session and Introduction
10:05-11:00	Presentations by speakers and questions Moderator: Institute for Energy Diversification and Saving (IDAE)
	ACCIONA ESCO
	AEDIVE
	AELEC
	AMPERE ENERGY
	APPA RENEWABLES
	WIND ENERGY BUSINESS ASSOCIATION
11:00-11:35	Questions and reflections from the audience
11:35-11:55	Rest
11:55-12:55	Questions and reflections from the audience
12:55-13:00	Close

3RD SESSION. TECHNOLOGICAL DEVELOPMENT CHALLENGES FOR STORAGE (R&D&I)	
SCHEDULE:	**ACTIVITY**
10:00-10:05	Opening of the Session and Introduction
10:05-11:00	Presentations by speakers and questions Moderator: General Secretariat for Innovation (Ministry of Science and Innovation)
	BATTERY PLAT
	CIEMAT
	NATIONAL HYDROGEN CENTRE
	TECNALIA
	CDTI
	CIUDEN (Energy City)
	UNIVERSITY OF LERIDA
	CIC energiGUNE
11:00-11:35	Questions and reflections from the audience
11:35-11:55	Rest
11:55-12:55	Questions and reflections from the audience
12:55-13:00	Close

4TH SESSION. INTELLIGENT INTEGRATION OF SECTORS	
SCHEDULE:	**ACTIVITY**
10:00-10:05	Opening of the Session and Introduction
10:05-11:00	Presentations by speakers and questions Moderator: Deputy General Directorate of Hydrocarbons and New Fuels (Ministry for Ecological Transition and the Demographic Challenge):
	EUROPEAN COMMISSION
	PROTERMOSOLAR
	ENAGAS
	AEH2
	AOP
	IMDEA
11:00-11:35	Questions and reflections from the audience
11:35-11:55	Rest
11:55-12:55	Questions and reflections from the audience
12:55-13:00	Close

5TH SESSION. CROSS-CUTTING ISSUES	
SCHEDULE:	**ACTIVITY**
11:00-11:05	Opening of the Session and Introduction
11:05-12:10	Presentations by speakers and questions Moderator: Subdirectorate General for Energy Planning, Strategy and Regulation (Ministry for Ecological Transition and the Challenge Demographic):
	GREENPEACE
	RESCooP EU
	RENEWABLE ENERGY
	BEEPLANET
	SARGA
	R2M
12:10 – 12:55	Questions and reflections from the audience
12:55 – 13:00	Close