D4.1: Analysis of financial support options for the Spanish value chain of key clean technologies.

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Executive Summary

As part of the strategies to overcome the impacts of the COVID 19 pandemic, Spain has structured the ***Recovery, Transformation and Resilience Plan*** *(RTRP) to guide the implementation of the European Union's* ***Next Generation programme*** *resources, which is implemented through the* ***Recovery and Resilience Facility (RRF)****. The Project '****Implementation and Monitoring of the Spanish Recovery and Resilience Plan for the Green Transition'*** *aims to support the monitoring, evaluating and management of the green components of the RTRP. This report is delivered as part of Deliverable 4 as part of this project, in which Trinomics, in association with 9 partner organisations, collaborates with the European Commission, MITERD and IDAE. This report responds to Task 4.1 Analysis of financial support options for the Spanish value chain of key clean technologies.*

Introduction

To reach the Spanish and European Climate target of climate neutrality in 2050, many **key clean technologies** have to be swiftly upscaled. The necessary climate and ecological transition presents both huge challenges and opportunities for Spain. Swift upscaling of the clean technologies and building up a solid value chain is a massive challenge, but also will provide Spanish industry with new opportunities to build up the value chain of key technologies both in Spain and globally, which eventually can contribute to increased competitiveness of Spain and provide ample local employment opportunities.

This report presents an initial review of the **key barriers** in Spain for upscaling the most important key clean technology value chains and subsequently presents first directions on how **financial support** of the Spanish government -led by MITERD and IDAE can help overcome those barriers. The key clean technologies (CET) covered in this review are: **wind power** (on- and offshore), **solar PV, energy storage, hydrogen** (electrolysers mainly), **electric mobility** and **heat pumps**.

The barrier review are based on a **literature review** in which preliminary barriers were identified. These barriers were then checked through 21 **interviews** with industry stakeholders in the CET value chains. We take into account the following segments per value chain: a) sourcing of materials and compounds; b) manufacturing of components and pre-assembly; c) logistics; d) construction and installation; e) operations and maintenance f) decommissioning, lifetime extension or recycling; g) broader enabling factors.

Identified value chain barriers

Our analysis shows that Spanish energy policy and the clean value chains have **improved substantially** since 2018. However, there is evidently room to further improve policy, and our analysis helps with identifying and prioritizing efforts in the near future. **Most identified barriers are regulatory** and are not directly due to a lack of (public) financing. Still, there is a need for financial support as part of a balanced policy mix. Even more so, a solid regulatory framework is needed to enable the effective use of public financing schemes. Hence, both are interlinked and should be approached in tandem. Next to this, stable, simple and predictable policies are needed to keep attracting investments in Spain.

The **main barriers identified are not technology-specific and impact all value chains**, both in Spain and in the EU. This makes an overarching strategy to tackle these barriers a necessity. We identify the following main overarching barriers (though this list is not exhaustive):

- **Lack of human capital:** a shortage of skilled labour is impacting all value chains. In some cases there are current shortages (e.g. installation solar PV), while in others a lack of skilled personnel could become a bottleneck on the short-term (e.g. heat pump installation of charging infrastructure rollout).
- **High supply chain dependency on China combined with protectionist support policies outside of the EU:** The EU and Spain are very dependent on China in most stages of key value chains, especially for batteries and solar PV. This creates substantial risks if supply from China decreases. Next to this, East Asia and recently the US are trying to attract clean tech businesses through subsidies with protectionist elements. This combination could lead to reduced economic opportunities in the EU and increase its dependency. The recent Green Deal Industrial Plan is a first step towards an European response to these risks and barriers.
- **Current energy infrastructure lagging behind development of renewable energy production:** Infrastructure investment lead times are generally slower than the scale up of renewable production (and demand). Hence, planning and public support on the short-term is needed to mitigate a lack of infrastructure becoming a larger barrier. Upgrading the electricity grid is notably important and forms the backbone of a decarbonized energy system. Hydrogen infrastructure also still has to crystallize.
- **Electricity market regulatory framework not fully in line yet with renewable energy system.** Though regulatory frameworks on EU and Spanish level have improved and better fit a renewable energy system, there is room for further finetuning and improvement. Stakeholders especially mentioned a lack of regulatory incentives for energy storage and slow permitting procedures for solar PV and wind.
- **Lack of RD&I support:** a lack of (targeted) RD&I support leads especially to barriers when scaling up innovations towards commercial viability. Addressing this becomes more important and offers new opportunities if Spain decides to invest more in manufacturing activities in the value chains.

Guidance on financial support needs

Both regulation and financial support is needed to further rollout key technologies in Spain. In the last part of the report, we specifically focus on where **financial support** is required, although a regulatory basis is needed to effectively use public financial support. Public financial support is justified when the objective of investments is in the wider public interest and if there are market failures to be covered.

In this chapter we analyse where financial support could be best directed. We've found 4 main financial support areas, which address the barriers found in previous chapters. Chapter 9 also includes many examples in other countries on how public financing is used. The support areas are:

- **Upgrading human capital**: financial support is needed to develop training and reskilling for green jobs throughout all value chains.
- **RD&I development:** Financial support is especially needed in the scale up phase (higher TRLs), also for manufacturing innovations, if Spain wants to increase its manufacturing capacity in different stages. Public-private partnerships are a proven and cost-effective way to gather finance.
- **Manufacturing and recycling support:** Find out where Spain's competitive advantage lies to increase clean tech manufacturing. Especially recycling activities are not economically viable

without financial support and hence need support. Financial support should go hand in hand with regulation, such as via requirements in Ecodesign regulation.

- **Infrastructure development:** Large public infrastructural investments are needed, especially in the electricity grid, including charging infrastructure and connections of solar and wind farms. Public finance is also needed to adapt ports for offshore wind development.

The most common instrument identified to cover some of these barriers are in the form of grants. Nonetheless, financial support could also come as: refundable grants, soft loans, direct equity or through funds, first loss guaranties, etc. These schemes' objective is to leverage private capital depending on the profitability and bankability options of the project, the risk or complexity and the market failures the projects faces. Follow-up research should further work out how best to design financial support.

1 Introduction

1.1 Context

To reach the Spanish and European Climate target of climate neutrality in 2050, many **key clean technologies** have to be swiftly upscaled. Recent announcements by the European Commission on the European Union (EU) Green Deal Industrial Plan[1] and the proposed Net Zero Industry Act[2] bring industrial policy at the top of the EU policy agenda, with the overarching aim of enhancing domestic capacity for strategic technologies.[3] The necessary climate and ecological transition presents both huge challenges and opportunities for Spain. Swift upscaling of the clean technologies and building up a solid value chain is a massive challenge, but also will provide Spanish industry with new opportunities to build up the value chain of key technologies both in Spain and globally, which eventually can contribute to increased competitiveness of Spain and provide ample local employment opportunities.

As part of the strategies to overcome the impacts of the COVID 19 pandemic, Spain has structured the **Recovery, Transformation and Resilience Plan** (RTRP) to guide the implementation of the European Union's ***Next Generation* programme** resources. The Recovery Plan is implemented through the **Recovery and Resilience Facility (RRF)** which seeks to restore the growth potential of EU economies, foster post-crisis job creation, and promote sustainable growth. Furthermore, Spain has approved 12 large **Strategic Projects for Economic Recovery and Transformation** (PERTES) to enhance economic growth and competitiveness through public-private collaboration for key areas for the future of the Spanish economy[4]. Specifically dedicated to these chains are the PERTE ERHA for renewable energies, renewable hydrogen and storage, which will mobilize public investment 6.9 billion euros; the PERTE VEC for the development of the Electric and Connected Vehicle for 4.3 billion euros, and the PERTE for the Circular Economy, which has a budget of 492 million euros.

Within this context, the Project **Implementation and Monitoring of the Spanish Recovery and Resilience Plan for the Green Transition**, approved by the European Commission's (EC) Directorate General for Structural Reforms Support (DG REFORM)[5] , aims to support the challenge of monitoring and evaluating the green components of the RTRP and managing its investments, as well as implementing some sectoral reforms in key issues for the ecological transition, such as energy storage and renewable energies. This report is delivered as part of Deliverable 4 as part of the project, in which Trinomics, in association with 9 partner organisations, collaborates with the European Commission, MITERD and IDAE.

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[1] COM(2023) 62 final - A Green Deal Industrial Plan for the Net-Zero Age.

[2] COM(2023) 161 - Proposal for a regulation of the European Parliament and of the Council on establishing a framework of measures for strengthening Europe's net-zero technology products manufacturing ecosystem (Net Zero Industry Act). Published on 16 March 2023.

[3] The proposed Net-Zero Industry Act sets an overall headline benchmark aimed at ensuring that by 2030, the manufacturing capacity in the Union of the strategic net-zero technologies approaches or reaches at least 40% of the Union's annual deployment needs. The overall headline benchmark takes into account the need for scaling up manufacturing capacity not only for end-products but also for specific components. It should be noted that up- and downstream supply chains (e.g. raw and processed inputs) are not set to be included in the scope of this Act. NZIA applies to final products, specific components and specific machinery primarily used for the production of a list of strategic technologies.

[4] Spanish PRTR – PERTE. https://planderecuperacion.gob.es/preguntas/que-son-los-perte

[5] Through the European Union's Technical Support Instrument (TSI).

1.2 Objectives and scope of the document

This report responds to Task 4.1 Analysis of financial support options for the Spanish value chain of key clean technologies. Its main objective is to support the Spanish government (namely MITERD and IDAE) to identify possible financial measures to support the value chain of selected key energy technologies.

The key clean technologies covered in this review are:

- **Wind power** (on- and offshore)
- **Solar PV**
- **Energy storage**
- **Electric mobility (EM)** (short analysis)
- **Hydrogen**
- **Heat pumps** (short analysis)

We provide a first compact overview of the **value chains** in Spain of several key clean technologies, with the aim to **identify potential barriers for upscaling** of these **value chains** in Spain. Secondly, we present **guidance for suitable lines of financial investment and support (e.g. financial instruments, support schemes, subsidies)** to overcome upscaling barriers.

We take two main perspectives for this analysis:

1. First, this deliverable has a **technological perspective** in which we focus on the timely availability of the required technology. Previous research using this perspective[6,7] has identified critical elements of the energy technologies value chains in Europe, predominantly, in the raw materials and compounds block of the supply chain. The criteria considered by these studies to select the highly vulnerable elements of the value chain included the assessment of import dependency, market concentration, easiness of substitutability and price stability.
2. Secondly, we take an **economic opportunity perspective** where we look at the business opportunities for Spanish companies which developing these value chains offer.

As a result, other aspects, while very relevant for the technologies, are not the main focus in this broad overview analysis. Most notably, the regulatory perspective is taken into account, but has been given less attention relative to its importance. Given the broad scope, we'd like to restate that this report should be used as a first guidance document.

1.3 Methodology

To answer the research question, a **literature review** is done of the value chain (barriers) both in general and in Spain to provide a preliminary overview of the value chains and possible needs and barriers. More concretely, the value chain segments of the energy technologies that we examine are as follows:

- **Sourcing of materials and compounds:** this phase involves the mining and preparation of the materials and compounds which are necessary for manufacturing the elements of a technology and associated equipment;

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[6] European Commission – DG RTD. (2017). Study on energy technology dependence.

[7] Trinomics (2021), Study on the resilience of critical supply chains for energy security and clean energy transition during and after the COVID-19 crisis

- **Manufacturing of components and pre-assembly**: in this phase the main components are manufactured and components are pre-assembled to a state that enables onsite construction and installation.
- **Logistics (transport and distribution):** this phase broadly describes the logistical set-up and infrastructure required for the components to be transported to the site of installation;
- **Construction and Installation:** this phase includes all the necessary construction, installation and commissioning works needed for the technology to operate and e.g. export electricity to the grid;
- **Operations and Maintenance:** this phase describes the products and services required to ensure ongoing operations of the technology project;
- **Decommissioning or lifetime extension:** this phase deals with the necessary activities to extending the life of the technology, or removing all elements of the technology from the project site at the end of its useful life.
- **Enabling factors:** There are other relevant aspects that shape how an energy technology chain, its inputs, services and finance operate. Institutions, including National and local authorities, often have an important role to play to generate an enabling environment, comprising regulatory, social and economic factors. A key feature of this document is to go beyond a comprehensive description of enabling factors for the energy technologies and their general importance, and focus on highlighting how specific elements of the environment affect the technologies' chains

The preliminary findings from the literature review are then discussed and refined through a broad range of **interviews with stakeholders**, mainly with relevant sector associations and public investment institutions. These interviews provide a perspective on the Spanish market needs. Finally, insights from the literature review and interviews are combined and then used to refine the value chain analysis and develop directions for financial and non-financial policy needs.

The **stakeholder interviews** were conducted using a structured model, based on a script that was previously sent to the interviewees, which included a description of the objective of the activity and a series of questions that were grouped into three sections:

1. Description of the Association/Company and characterisation of the sector in Spain and Europe
2. Barriers
3. Policy Measures

In total, 21 interviews were conducted, incorporating the perspective of 24 sectoral actors[8] , which were scheduled (although not strictly limited)for one hour. The full list of organisations and actors interviewed is available in Annex I List of interviews. The choice of actors to interview was made under the criterion of having multiple perspectives of each value chain, for which at least one industry association was contacted in each of them, providing a transversal view of the sector, and as far as possible, companies of different sizes and active in different segments of the technologies' value chain.

The interviews were conducted virtually between 9 February and 13 March 2023. Permission was also requested to include the name of the association/company and the interviewee in this document, clarifying that the expressions made would not be published as quotations. In the introduction of all the

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[8] In one case, the interviewee represented an association and owned a company, and responded from both perspectives, and in another, a company that supplied components for three value chains was interviewed.

interviews, it was emphasised that the main objective was to identify the barriers faced by the sector, in order to find out the possible policy measures, financial or otherwise, that from the interviewees' perspective the Spanish government should implement in order to overcome these barriers.

The technology value chain chapters (chapter 4 to 7) broadly follow the same structure:

- **General overview of the value chain on European level:** introduction to the technology and summary of how the value chain in general looks.
- **Mapping the value chain and barriers in Spain:** This main section then zooms in on the specific identified barriers in the value chain that are relevant for Spain. For heat pumps and electric mobility the first two sections are combined.
- **Summary of barriers in Spain for the value chain**: section summarizing the main identified barriers and needs in all value chain sections.
- **Mapping of existing (Spanish) initiatives related to the value chain:** this section includes an overview of the existing support schemes from the Spanish Government (via MITERD or IDAE) related to the value chain. For heat pumps this segment is not included, as no relevant support schemes were identified by this study.

Chapter 8 summarizes the value chain analyses and presents the conclusions on barriers of this research.

Though not all barriers are financial barriers, In chapter 9 we zoom in on how to design support that could contribute to overcoming the financial barriers. This section provides an overview of potential financial support schemes, which can be used to further research and design the most viable financial support for the value chains.

2 Wind Power

Wind turbines have become a mature and highly sophisticated electricity generation technology, with Spain being both a frontrunner in parts of the value chain as well as the use of wind power. As of 2022, over 29.417 GW of wind power generation installed capacity is in operation in Spain.[9] Almost all of this installed capacity is on-shore. This capacity is aimed to grow to 50GW via the Spanish government's offshore wind and marine energy roadmap details in the PNIEC.[10] This roadmap also emphasizes growth of offshore wind capacity, and sets the shorter-term objective of 1-3 GW of offshore wind power capacity by 2030.[11] Spain currently has 1,298 wind parks with 21,574 wind turbines.[12]

Spain is currently the third largest exporter of wind turbines in the world. The wind energy sector directly employs more than 32,087 professionals and around 1,655 are focused on offshore wind, while it indirectly induced employment of 8,533 people, leading to estimates of total employment in Wind Power in Spain reaching 40,620 people.[13] Wind power contributes over 3 billion euros to the Spanish GDP, covering the whole value chain.[14] Spain has 250 manufacturing centres.[15] With regards to offshore wind, Spain has 6,000 km of shore with stable and abundant wind resources, providing an opportunity to further develop offshore wind. Due to its coast's characteristics, floating foundations are the most suitable technologies to exploit Spain's offshore wind potential.[16] Even though there has been expressions of interest to develop the technology in the Iberian peninsula, there is limited installed offshore wind capacity in Spain[17], with the only ongoing projects being R&D facilities for floating wind power and other marine energy technologies.

For this assessment report, the value chain of onshore and offshore wind energy technologies has been investigated to identify the most relevant barriers and needs. As onshore and offshore wind energy share most of the barriers and needs, they are assessed together. Where key barriers are of particular relevance for either onshore or offshore wind energy, this is indicated.

2.1 Wind power value chain at EU level

In general terms, the main components of the wind power value chain include:

1. **Sourcing of raw materials and compounds** – the materials and compounds which are necessary for manufacturing the elements of onshore and offshore wind turbines and associated equipment include Copper, Steel, Molybdenum, Rare Earth Metals, Fibre-Glass for the Wind Turbine blades, and Insulation Materials for High Voltage Cables. Europe relies on imports for most these elements, however, previous studies on critical supply chains of energy technologies[18] highlight copper and rare earth elements (Dysprosium and Neodymium) as the more vulnerable elements

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[9] MITECO (2021), Hoja de ruta eólica marina y energías del mar en España.

[10] MITECO (2020), Plan Nacional Integrado de Energía y Clima (PNIEC) 2021-2030.

[11] Gobierno Español (2021), Hoja de Ruta Eólica Marina y Energías del Mar en España

[12] Sistema Electrico REE (2023). Potencia instalada Información elaborada con datos provisionales a enero del 2023.

[13] AEE (2022). Estudio Macroeconómico del Impacto del Sector Eólico en España 2021.

[14] AEE (2022), Catalogue Spanish Wind Industry

[15] AEE (2022), Anuario eólico 2022

[16] Gobierno Español (2021), Hoja de Ruta Eólica Marina y Energías del Mar en España

[17] NTTdata (ongoing), Support to REPowerEU - Supply chain dependencies.

[18] Trinomics (2021), Study on the resilience of critical supply chains for energy security and clean energy transition during and after the COVID-19 crisis

for wind turbine construction in Europe. The IEA also considers nickel, chromium, zinc, and aluminium as critical minerals.[19]

2. **Manufacturing of equipment and components** – The basic elements of the wind turbines can be grouped in the Nacelle and Rotor assembly, and the Balance of the Plant. The Nacelle and Rotor assembly includes all components to convert kinetic energy of the wind to electric energy (the nacelle structure, generators, electrical and control systems, etc.) The Balance of Plant includes the support structure, electrical equipment and communications equipment needed for transporting the electrical energy to the grid, while the installation of offshore wind parks also requires foundations or floating structures. Due to the high costs of shipping turbine components, such as blades, nacelles, platforms, towers and vessels, currently only less than 20% of their global output is traded inter-regionally.[20] Europe has high manufacturing capabilities in components with a high share in wind turbine manufacturing costs (such as towers, gearboxes and blades), as well as in other relevant components (e.g. generators, power converters and control systems). Five of the 10 biggest wind turbine manufacturers in the world are based in the EU (as of 2021), and together, European manufacturers account for ~35% of the global wind turbine value chain.[21] Manufacturing plants in Europe mainly serve the onshore wind segment. For offshore wind, due to their large size, manufacturing sites need to be located close to the shore, with turbine pre-assembly often happening in shipyards.
3. **Logistics (transport and distribution)-** Ports and public-road infrastructure play an important role for the logistics of onshore and offshore wind. Offshore wind activities need to be included into the planning of the national transport network. Member States need to adapt its port facilities and services to the needs arising from the large-scale development of offshore wind energy. Ports are also particularly relevant for the installation and construction of offshore wind parks. Shipyards and the ancillary naval industry can act as logistic hubs for pre-assembly of large wind turbine components and loading onto the ships that transport them. However, ports need to be adapted to provide quayside access to both supply chain and service operation vessels. Moreover, these ports must provide appropriate sites to support efficient and large-scale turbine installation processes for manufacturing and construction companies.[22]
4. **Construction, installation and O&M –** O&M activities are developed over the operating life of the installations (approximately 30 years). In the case of offshore wind, crew transfer vessels, service operations vessels for technician and equipment transfer, and the provision of services such as diver support and cable maintenance are central for operation and maintenance. Seasonal restrictions (e.g. in winter) are to be expected, which could be mitigated by the use of helicopters for flight maintenance, and in the future, drones have been identified as a possible tool for O&M.[23]
5. **Decommissioning or lifetime extension:** Most of the turbine component materials can be recycled, but they are usually sent to landfill upon decommissioning.[24] Blades are currently made of composite materials which are challenging to recycle in a cost-effective way.

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[19] IEA (2020), The role of Critical Raw Materials in Clean Energy Transitions

[20] IEA (2023). Energy Technology Perspectives 2023.

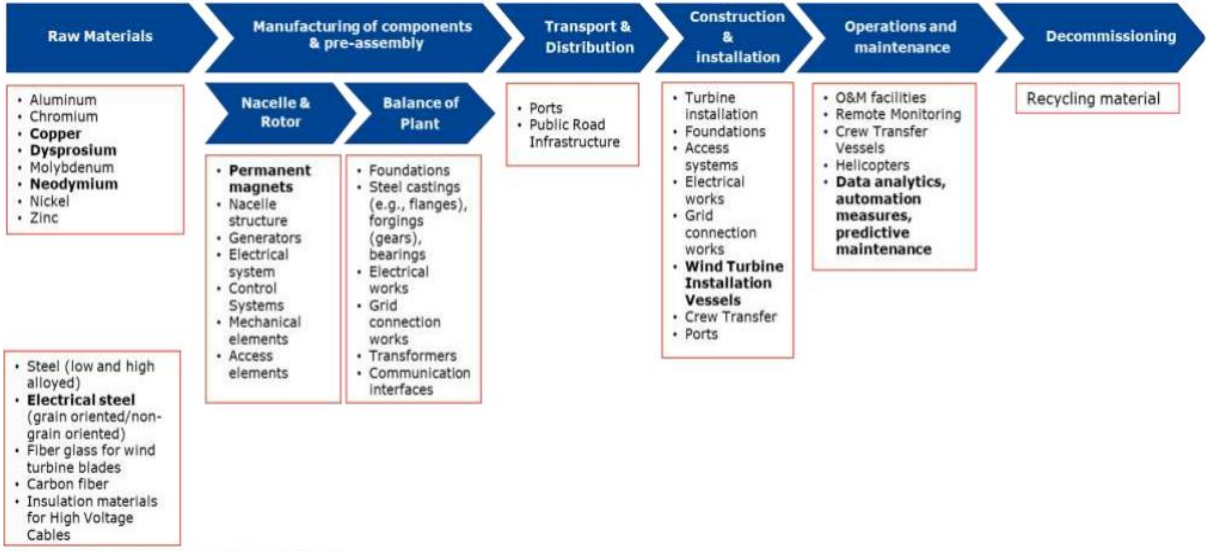
[21] Trinomics (2021), Study on the resilience of critical supply chains for energy security and clean energy transition during and after the COVID-19 crisis

[22] Gaia Consulting & Trinomics (2022), Financing SDG Transformations - Experiences from four sustainable finance pilot ecosystems

[23] Ibid.

[24] EurObserv'ER (2022). Wind Energy Barometer 2022.

Figure 2-1 - A simplified value chain for wind power. Source: Trinomics (2021)[25]



Note: vulnerable elements found highlighted in ***bold****.*

It is relevant to notice that offshore wind farms require several studies and positive assessments prior to the project authorization. These include a positive Environmental Impact Assessment, a study on the compatibility of the facility with other uses of the maritime space (e.g. fishing and navigation), seabed studies and water depth to determine the types of foundation concepts needed for the site, and studies to ensure the proposed solutions do not cause disturbance to national defence's radar.[26] For design and engineering, these include the technical designs of the offshore site, the turbines layout, electrification plan, calculations of the energy production, definition of a budget and schedule for the construction project, and other supporting analysis.[27] These activities might include synergies with other sectors, such as construction, civil works, naval construction, etc.

Textbox 2-1 Cost estimations along the value chain for offshore wind. Source: AEE (2022)[28]

The investment costs of offshore wind parks are highly dependent of project specific features, based on the water depth and distance to the shore. Moreover, the investment costs vary depending on the type of offshore wind installation, namely whether it uses fixed foundation or floating platforms.

Recent estimates of CAPEX for 2025 provide comparisons of the breakdown of the main investment costs per MW for a 500 MW fixed foundation offshore wind farm vs a floating offshore wind farm. (see **Error! Reference source not found.** below). Overall, CAPEX for floating offshore wind is higher than those for an offshore wind fixed foundations. Turbines for floating installations are costlier, as they tend to be larger in size , while elements such as grid connection and cable array are also more expensive, given the distance to the shore is larger than installations using fixed foundations. The main element that is more expensive for offshore wind parks using fixed foundations is the installation of the wind park, which is mainly due to activities related to driving the foundation to the sea floor.

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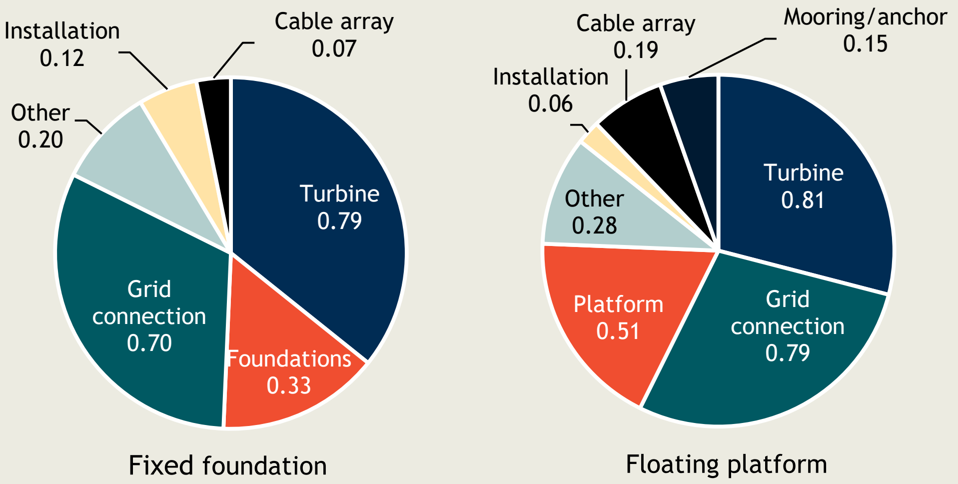
[25] Trinomics (2021), Study on the resilience of critical supply chains for energy security and clean energy transition during and after the COVID-19 crisis

[26] Gaia Consulting & Trinomics (2022), Financing SDG Transformations - Experiences from four sustainable finance pilot ecosystems

[27] Ibid.

[28] AEE (2022). Libro blanco de la industria eólica marina en España.

Figure 2-2 CAPEX breakdown of a 500 MW offshore wind farm by type of installation: fixed foundation and floating platform (Millions of euros/MW installed, estimates for 2025). Source: BloombergNEF via AEE (2022).



With regards to estimates of costs related to the Operation and Maintenance activities (OPEX) of fixed foundation offshore wind parks, estimates suggest that operating costs would be in the range of €30.26 million/MW, while maintenance costs could be in the range of €61.41 million/MW.[29] It should be noticed these are first estimates and could drastically vary , as the market is still in its infancy and lacks comparable long-term experience given the immaturity of the technology.

2.2 Mapping the wind power value chain in Spain

Previous research has shown that Spain already hosts a fully-fledged competitive value chain exporting components and providing services for onshore and offshore wind parks across Europe.[30] In order to benefit from the ongoing development of wind power, the Spanish industry is still facing pressing challenges, which are described below.

2.2.1 Sourcing of raw materials and compounds

Wind turbines are built using many materials, including concrete, steel, glass and/or carbon composites, polymers, aluminium, copper, chromium, zinc, manganese, molybdenum, and multiple **rare earth elements** (REE; namely dysprosium, neodymium, and praseodymium).

Steel is one of the main materials used for both onshore and offshore wind turbines. Industry stakeholders pointed out that although there is steel production in Spain, most of the steel used in the manufacturing of equipment and compounds is sourced from outside of Spain, and often from outside of Europe. Some stakeholders listed supply constraints from local steel suppliers due to their production processes as a cause for turning to imports from external suppliers outside of Europe . Overall, the steel market, as well as the rest of the materials listed are global markets with strong competition from Asian suppliers. Spanish stakeholders noted that import tariffs on raw materials such as steel protects European metal manufacturers, but puts the component manufacturers at a disadvantage by considerably increasing their production costs. To have a level playing field between , import tariffs on raw materials from non-EU countries should ideally be accompanied by similar import tariffs on finished components, restrictions in

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[29] Based on estimates from BVG Associates/Catapult – Wind Farm Costs and Wood Mackenzie – Global Bottom-fixed offshore wind operations and maintenance 2021. Via AEE (2022). Libro blanco de la industria eólica marina en España.

[30] AEE (2022). Manifiesto por el Desarrollo de la eólica marina en España

carbon emitted during production and transport, and/or support measures to local production similar as those received by non-EU component producers.

Moreover, an analysis of supply chain dependencies, performed as part of an ongoing support for REPowerEU indicates that at the Spanish level, only REEs are considered as moderate risk for the supply chain, while the rest of the materials have a low risk.[31] Interviews with industry stakeholders further confirmed that Spanish dependencies on sourcing or processing of critical raw materials (including REEs) are not currently considered a significant barrier for the wind industry.

Table 2-1 Spanish dependency on needed critical minerals for wind power. Source: NTTdata (2022).[32]

Raw material	Need degree[19]	CRM?[20]	Reserves in Spain[21,22]	Mining Operations in Spain[23]	Dependency
Copper	High	NO	YES	YES	NO
Nickel	Medium	YES	YES	YES	YES
REEs	High	YES	YES	NO	YES
Chromium	Medium	NO	NO	NO	YES
Zinc	High	NO	YES	YES	YES
Aluminum	Medium	YES	NO	NO	YES

Currently, double-fed induction generators (DFIG) and permanent magnet synchronous generators (PMSG) are the primary technologies used in wind turbine generators.[33] DFIGs use little REEs and are common for on-shore applications. However, PMSGs use more REEs within permanent magnets, especially in a direct-drive setup. DD-PMSGs are common in offshore applications, due to their better performance and lower maintenance requirements. PMSGs, especially DD-PMSGs, are expected to make up 95% of the market for offshore wind and over 40% of the market for onshore wind by 2040. This creates a great dependency on REEs from wind power.

REEs are mostly sourced from China, where over 60% of the world's supply is mined and over 85% is refined.[34] Strong support from various governments, for example the US, has also pushed for local growth in REE supply (and permanent magnet manufacture).[35] Given that mining and refining operations take a long time to develop, dependency on China is expected to continue for the next 10 years.

Eventually, recycling wind turbine generator parts can recover enough REEs to oversupply Spanish REE demand.[36] Globally, about 90% of the wind turbine materials are recycled commercially (with Spain being further behind).[37] However, REEs are more difficult than other materials; yet it can be assumed that by 2030 they will begin to be recycled at similar rates.[38] This secondary supply of REEs will greatly reduce the need for primary supply via mining and refining operations.[39]

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[31] NTTdata (2022), Support to REPowerEU - Supply chain dependencies

[32] Ibid.

[33] Electrically excited synchronous generators (EESG) are also used in wind turbines and have a small market share that is expected to remain small. In situations with high REE constraints, these low-REE options may gain market share in the coming decades. Source: IEA (2022), The Role of Critical Minerals in Clean Energy Transitions.

[34] GWEC (2022), Global Wind Report 2022

[35] White House (2022) FACT SHEET: Biden-Harris Administration Announces Further Actions to Secure Rare Earth Element Supply Chain.

[36] KU Leuven (2022), Metals for Clean Energy: Pathways to solving Europe's raw materials challenge.

[37] GWEC (2022), Global Wind Report 2022

[38] KU Leuven (2022), Metals for Clean Energy: Pathways to solving Europe's raw materials challenge.

[39] Ibid.

Textbox 2-2 Wind turbine materials use

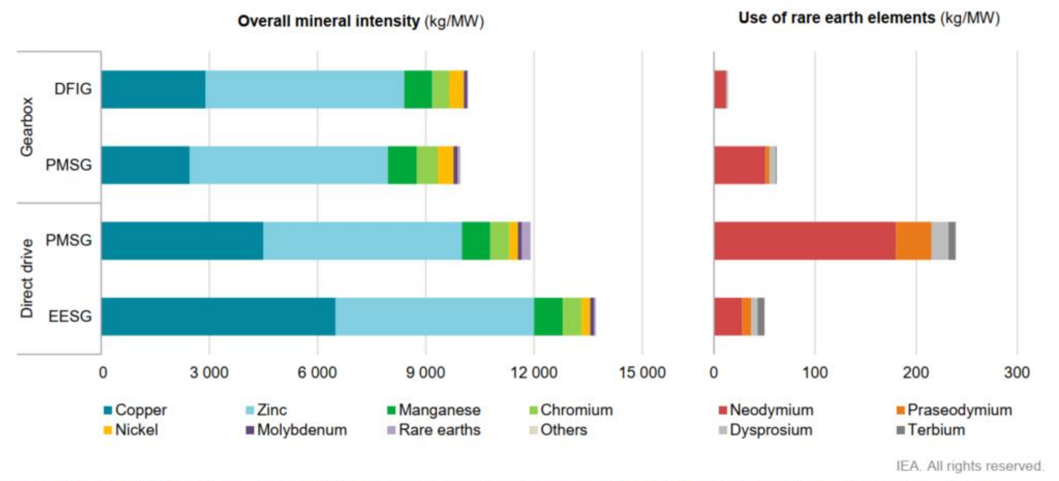
Wind turbines use an array of materials in their production. These materials include concrete, steel, glass and/or carbon composites, polymers, aluminium, copper, chromium, zinc, manganese, molybdenum, and multiple REEs (dysprosium, neodymium, and praseodymium). Depending on whether a turbine is on-shore or offshore, it would have different materials used in its construction. In terms of weight, most of the materials used in lighter off-shore turbines is steel, while heavier on-shore turbines have more concrete and steel in their structures. Copper use in offshore turbines can also be twice as high as onshore turbines, due to use in submarine cables:

Figure 2-3 - Source: GWEC (2022), Global Wind Report 2022

Source: BloombergNEF Note: GFRP = Glass fiber reinforced plastic. CFRP - Carbon fiber reinforced plastic.

Wind turbine generator setups use some critical and expensive components and materials, which differ depending on technology. Gearbox-based designs use the lowest amount of materials, including REEs, but more recent options with direct drives use more materials per MW of output. Moreover, PMSG generators use a high amount of REEs within their permanent magnets. EESG drives.

Figure 2-4 - Source: IEA (2022), The Role of Critical Minerals in Clean Energy Transitions



Notes: DFIG = double-fed induction generators; PMSG = permanent-magnet synchronous generator; EESG = electrically excited synchronous generator. The intensity numbers are based on the onshore installation environment. More copper is needed in offshore applications due to much longer cabling requirements.
Sources: Carrara et al. (2020); Elia et al. (2020)

2.2.2 *Manufacturing of equipment and compounds*

According to Spanish Wind Energy Business Association (AEE)[40], there are currently 115 companies in Spain dedicated to the manufacturing of components for wind turbines. Figure 2-5 below shows the location of these manufacturing plants, as registered by the AEE in 2021. Of the 115 companies mapped, 28 focus on

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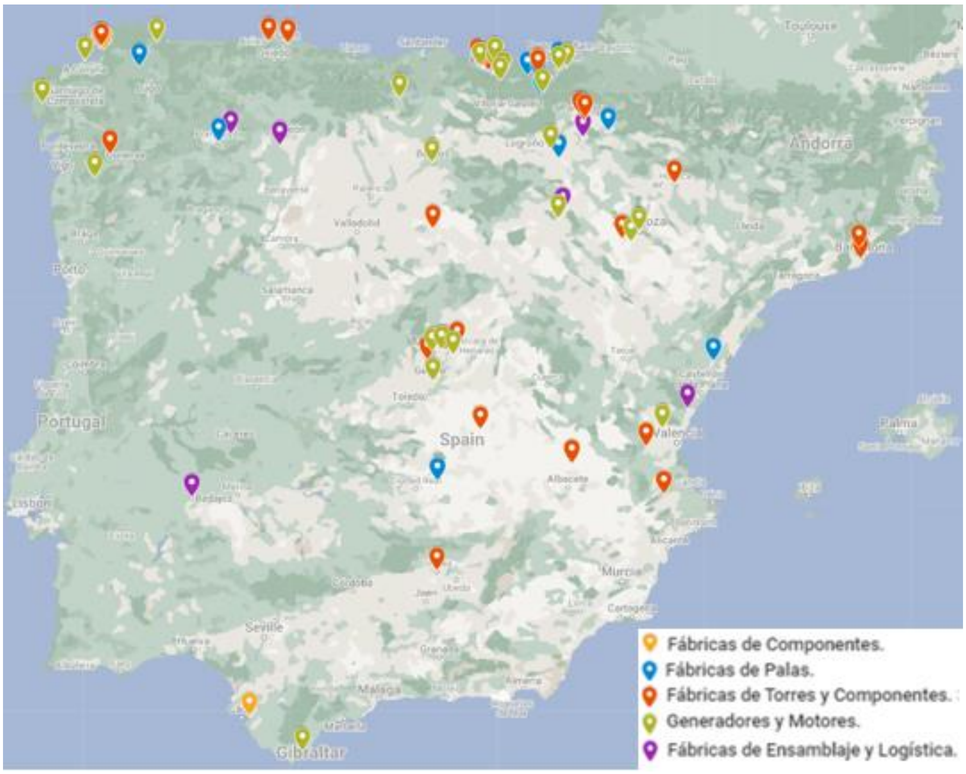
[40] AEE (2022). Libro blanco de la industria eólica marina en España.

wind power components, 28 manufacture wind blades, 32 manufacture wind towers, 25 have production activities related to wind turbine generators and motors, and 13 are factories where assembly of wind turbines and logistics. Moreover, an ongoing study *'Support to REPowerEU – Technical support for supply chain dependencies'*, concluded Spain has strong manufacturing capacities for the key equipment and components of wind energy, especially in blades and towers.

Figure 2-5 Location of manufacturing facilities of wind power equipment and compounds in Spain. Source: AEE (2021).[41]



Nacelles manufacturing, (which house the generator, gearbox, drivetrain and brake assembly) is the only equipment for which Spain is lacking on manufacturing infrastructure and capabilities. Currently Spain houses only one company active in manufacturing wind turbine generators (Siemens Gamesa). In the past Nordex was also active in this segment, but suspended production at its Spanish nacelle casing factory in 2020.[42] The manufacturing of wind turbine generators is mainly developed in Asia, especially in China, where the processing capacity and resource availability are higher (see Textbox 2-3 below).

Textbox 2-3 Global trends and market concentration of manufacturers of wind turbine components.).

The global market of wind turbine manufacturing has become more concentrated over the past years. The wind supply chain mainly comes from four regions: Europe, India, China and the United States (U.S.), with each of the regions producing all the major components in a wind turbine.[43] There are currently about five major players outside of China, down from 10 in 2015. There has been significant merge and acquisition activities, leading to only five companies accounting for 94% of all manufacturing installations outside of China in 2021.[44] Moreover, in 2022 the four Non-Chinese industry leaders include Vestas, GE Renewable Energy , Nordex and Siemens Gamesa reported

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[41] AEE (2021). Instalaciones eólicas España 2021.

[42] Energy Economic Times (2020). Wind turbine maker Nordex suspends production in Spain

[43] BloombergNEF (2022). Wind Power in 2020s Must Focus on Capability, Not Cost.

[44] BloombergNEF (2022). Wind Power in 2020s Must Focus on Capability, Not Cost.

lower revenues and worsening losses, citing supply chain disruptions and costs resulting from the effects of Covid-19 and Russia's invasion of Ukraine. [45]

The biggest European markets in terms of new wind installations are concentrated in 5 countries, namely the UK, Sweden, Germany, Turkey and the Netherlands.[46] With regards to Offshore wind, the UK, Denmark and the Netherlands where the only European countries with new installations in 2021[47]. New growth markets are also emerging in the United States, Chinese Taipei and Japan. In 2021 China's had the largest increase in capacity, with over 16.9 GW new capacity installed, Asian countries[48] are expected to dominate offshore wind markets in the future, with a projected installed capacity of 100 GW in 2030, and 600 MW by 2050.[49]

As of early 2023, capacity expansion plans of key onshore and offshore wind component manufacturing point to China maintaining its leadership position in the near future. China accounts for 80-90% of announced manufacturing capacity additions of onshore nacelles, blades and towers, and for offshore turbines it accounts for 35% of announced manufacturing capacity additions for nacelles, 75% for towers and 60% for blades. [50] The new emerging markets and local content requirements will likely start a trend in which supply chain companies are pushed to set up new factories in the U.S, Taiwan, Korea and/or Japan. [51] North America and Asia Pacific account for around 50% of announced expansions for offshore nacelles, while Europe cover 25% of all announced manufacturing additions for offshore blades. [52]

In the case of offshore wind components, Spanish companies mainly export their equipment and components, since currently there are no commercial activities of offshore wind parks in Spain. Key Spanish manufacturers of offshore wind turbines with productions sites in Spain, or with installed capacity outside Spain include Siemens Gamesa and Nordex Acciona Windpower. Moreover, Spain is the main supplier of floating foundations in Europe,11 of the 13 currently installed floating foundation solutions have been manufactured by Spanish companies.[53] Notably, Spain counts with most patents for floating foundation solutions and is a global leader in RD&I and technological development in offshore wind.[54] Other components of offshore wind parks in which Spain has manufacturing capabilities or the capacity to develop them include chains for anchoring systems for underwater structures, marine electrical substations in direct or alternating current and submarine cables. [55]

Overall, Spain already has infrastructure and key industry players dedicated to the construction of blades, towers and equipment for offshore wind, but the infrastructure needs to be scaled up.[56] In order to be suitable for adaptation, existing manufacturing facilities of blades and towers need to be located close to the shore, with the pre-assembly turbines often happening in shipyards. According to the AEE, the existing manufacturing installations in Spain can accommodate the larger components required for

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[45] IEA (2023). Energy Technology Perspectives 2023.

[46] Denmark, Ireland, Germany, UK, Portugal and Spain currently host the biggest shares highest share of wind in their electricity mixes, and with the Netherlands leading the way for new installations. Source: WindEurope (2021), Wind energy in Europe 2020: Statistics and the outlook for 2021-2025.

[47] WindEurope (2022). Wind energy in Europe: 2021 Statistics and the outlook for 2022-2026.

[48] The largest growth in offshore wind capacity is expected to happen in countries like China, South Korea, Japan, Indonesia, the Philipines and Vietnam. Source: AEE (2022), Anuario eólico 2022

[49] AEE (2022). Anuario eólico 2022

[50] IEA (2023). Energy Technology Perspectives 2023.

[51] BloombergNEF (2022). Wind Power in 2020s Must Focus on Capability, Not Cost.

[52] IEA (2023). Energy Technology Perspectives 2023.

[53] Manifiesto por el Desarrollo de la eólica marina en España

[54] Manifiesto por el Desarrollo de la eólica marina en España & AEE (2022), Anuario eólico 2022

[55] Ibid.

[56] Gobierno Español (2021), Hoja de Ruta Eólica Marina y Energías del Mar en España

floating wind, since they already have the needed capacity and are well located for the transportation of the products.[57]

According to industry stakeholders, the main challenges currently faced by Spanish manufacturers of wind turbine components is the increasing competition from Asian competitors. From the interviews conducted, it emerges that the main barrier to sustaining and boosting the wind energy sector, where Spain is already a world leader, is more in the form of a threat, and this threat is competition with China. These include:

- EU tariff policy: by setting tariffs on Chinese steel to protect the European steel industry, and not taxing Chinese components that include Chinese steel, European component manufacturers that use Chinese steel are put at a disadvantage.
- Chinese manufacturers receive support from the Chinese government, allowing them to be more competitive in terms of price. This situation stifles European companies when the selection criterion for a call for tenders is limited to price.

Another key challenge for wind energy manufacturing in Spain is the establishment of local content requirement in their export markets. Current trends on regulatory and trade policies are pushing manufacturers of wind turbine components to build their supply chains in countries in which wind parks are installed. Common policies used by countries include local manufacturing requirements, subsidies or incentives for building local manufacturing capacity, and import tariffs. According to the IEA, in 2023 more than 20 countries have implemented local content requirements for wind energy. [58] Notable examples include:

- In Brazil, developers need to use local equipment in order to be eligible for low-cost financing from the country’s development bank.
- In the USA, the IRA provides additional tax credits for domestic production of offshore wind components. To claim the additional credit, developers must certify that any steel, iron or manufactured product that is a component of a facility upon completion of construction was produced in the United States.
- Moreover, several countries, including Canada, Indonesia and Spain have imposed anti-dumping duties. The European Commission also imposed anti-dumping duties on imports of steel wind towers from China in 2021, ranging from 7.2% to 19.2%, after an investigation revealed that Chinese towers valued at around EUR 300 million were being imported at dumped prices. [59] Notably, in 2021 the United States imposed anti-dumping duties and countervailing duties with rates up to 73% on imported wind towers from Spain upon entry into the USA.[60] Spanish industry stakeholders reported these tariffs have put a halt to their exports to the USA.
- In the case of European Member States, the European legal framework does not facilitate the implementation of local content measures within each Member State, although countries such as France are starting to apply it based on ‘*good practice and voluntary commitments*’ (e.g. in France).[61]

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[57] AEE (2022). Libro blanco de la industria eólica marina en España.

[58] IEA (2023). Energy Technology Perspectives 2023.

[59] REGULATION (EU) 2021/2239 of 15 December 2021 imposing a definitive anti-dumping duty on imports of certain utility scale steel wind towers originating in the People’s Republic of China.

[60] WTO (2021). United States of America: Definitive antidumping duties on imports of utility scale wind towers from Malaysia and Spain. n

[61] WindEurope (2022). France commits to 40 GW offshore wind by 2050.

The stakeholder engagement activity revealed that the wind industry considers there is a link missing between renewable energy policies and industrial policies both at the EU and national level. They call for a national industrial strategy that is aligned with the existing and desired supply chain in Spain.

2.2.3 *Logistics (transport and distribution)*

Spain is host to a robust port network with potential to hold the industrial activity associated to offshore wind parks.[62] AEE's mapping of wind power installations in Spain lists 12 ports in the Spanish peninsula with offshore wind activities (see Figure 2-6 below). Spanish shipyards already have relevant experience in the construction of floating offshore structures, as well as being leaders in offshore moorings. The capabilities of these ports can be improved in order to serve the offshore wind supply chain, namely the manufacturing, assembly, operation, maintenance, and decommissioning of offshore wind parks. [63]

Figure 2-6 Spanish ports with offshore wind activities. Source: AEE (2021).[64]

Note: The ports shown are Puerto Castellón, Puerto Bilbao, Puerto Motril, Puerto Carboneras, Puerto Avilés, Puerto Ferrol, Puerto Valencia, Puerto Sagunto, Puerto Marín, Puerto Escombreras, Puerto Santander. Cantabría and Puerto de Sevilla.

WindEurope highlights the investment needs in European port infrastructure to enable the effective delivery of offshore targets within the National and Energy Climate Plans for future growth (see Table 2-2 below). Their estimates on the role of improving ports, port services and vessels in offshore wind LCOE reduction to 2030 result in combined saving of 5.3% of LCOE (approximately €2/MWh and or about €110,000/MW installed). [65]

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[62] Manifiesto por el Desarrollo de la eólica marina en España & AEE (2022), Anuario eólico 2022

[63] Manifiesto por el Desarrollo de la eólica marina en España & AEE (2022), Anuario eólico 2022

[64] AEE (2021). Instalaciones eólicas España 2021.

[65] WindEurope (2021). A 2030 Vision for European Offshore Wind Ports.

Table 2-2 Overview of investment needs and costs for infrastructure works in ports. Source: WindEurope (2021).[66]

Investment item	Cost per investment
Upgrading facilities for a port already in the bottom-fixed offshore wind business	€20-80 million
Building a new energy port/terminal for bottom-fixed offshore wind (around 15-20ha)	€80 - 110 million
Building a decommissioning facility/ refurbishing an existing facility in the port	€5-10 million
Floating port adaptations or new terminal	€200 million
Infrastructure for renewable hydrogen production in ports	€100 million
Accommodating energy island operations, products, and related infrastructure	€500 million

Industry stakeholders consider that Spain has particularly favourable port conditions to support the development of offshore wind supply chain, both in terms of location, coastal characteristics and existing infrastructure. In comparison with other countries that have to build port infrastructure from scratch, while Spain can rely on updating its existing ports. The main (and only) challenge mentioned as relevant barrier for the required adaptations are the large investments required for it. For instance, there are no notable environmental restrictions, since ports already exist. On the other hand, creating a new port, as for example in the Canary Islands, can cost around €100 million and can take up to 8 years to build.

Port adaptations have to be carried out by the respective Spanish port authorities, with public finance. Port authorities own the land in ports, and provide concessions of land to private companies via tendering processes. Once companies win a space in the port, they need to make adaptations to the space to make it operable.

Offshore activities in ports compete with other industry activities that can provide higher returns in the short-term, such as cargo logistics. To overcome the infrastructure challenges and costs associated with upgrading ports to deal with the growth of the offshore wind sector, national authorities are urged to provide **long-term revenue certainty** for the exploitation of these facilities as part of the national energy policies. To this end, a **favourable regulatory environment,** together with **financial backing for ports infrastructure** development could provide confidence to industry players in the value chain and lower the investment risk associated with the activity.

There is also need for transport and logistics equipment. These include specialized vessels for the transportation and installation of the turbines, as well as foundation installation vessels which . Vessels for cable-laying and substation installation are also necessary, which also can be done by Spanish companies with prior experience related to oil and gas extraction. Globally, there is only a limited number of vessels available that are suitable for offshore wind installation and operation:

- There are currently around 15 wind turbine installation vessels offshore wind farms, with confirmed orders increasing the fleet size up to 28 by 2026.[67]
- In the case of foundation installation vessels, the current fleet of 22 ships is expected to increase to 24 by 2026.Most of these are also commonly used by oil and gas companies, while 14 of these vessels (the larger range) are also used for installing foundations of offshore substations.
- In 2023 there were 31 dedicated cable-laying vessels, with only one new addition to the fleet expected in 2024.

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[66] WindEurope (2021). A 2030 Vision for European Offshore Wind Ports.

[67] Wind Europe (2022) Offshore wind vessel availability until 2030: Baltic Sea and Polish Perspective.

- Besides the previously listed large construction vessels, an variety of smaller vessels support the operations . The majority of these offshore support vessels are not built purposely for offshore wind , and are crucial for offshore operations of the oil and gas industry. Offshore wind developers and contractors tend to contract vessels with the right specifications, such as DP, high workability, sufficient deck space, low emissions and modern facilities on board. The expected demand for suitable vessels poses in the second half of the decade poses an opportunity for smaller sized shipyards, for the conversion and upgrade of existing vessels or for the new build of assets.
- Finally, service & operation vessels, as well as crew transfer vessels are used for daily windfarm maintenance. There are currently 32 service and operation vessels in operation on offshore wind farms worldwide, and by 2030 the fleet could go up to 100 vessels.

With the expected increased deployment of offshore wind in Europe in the world, we can expect demand for these vessels to also increase. Currently, none of the operators of the large offshore wind construction vessels are based in Spain, however, this is not deemed inherently problematic by industry stakeholders and topic experts. The Spanish offshore wind sector does not need to have inhouse operation of these vessels, instead it mainly needs to ensure access to the limited number of the specialized vessels available. At the same time, given that the future development of wind energy points toward floating offshore wind, industry stakeholders expect these large ships to become less critical 10 years from now. Moreover, the expected rise in demand for suitable (smaller) offshore support vessels can be considered an opportunity for Spanish shipyards.

2.2.4 Construction, installation and O& M

Spanish companies have strong capabilities and proven experience in developing, installing, operating and maintaining onshore wind farms inside and outside of Spain, together with strong industrial capabilities and know-how linked with the naval sector.

Figure 2-7 below shows the location of the 128 installations of maintenance of wind power in Spain, as registered by the AEE in 2021.The industry stakeholders remarked that Spain has a significant shortage of qualified professionals, and a lot of competition between companies and sectors.

Figure 2-7 Location of installations of maintenance of wind power in Spain. Source: AEE (2021).[68]

Support for this segment in the offshore wind sector is mainly needed for **the training of professionals in the activities of offshore wind value chain** related to construction, installation as well as operations and maintenance to match the expected rise in demand. There is a consensus among the interviewees that there is a shortage of personnel linked to the trades (medium technicians, welders, assemblers, etc.), which constitutes a bottleneck in the event of a revival of the sector. The biggest shortage of personnel was reported to occur amongst **offshore wind operator** positions. According to industry stakeholders consulted, it is imperative to align training programmes and combine this with wage policies that give companies more flexibility when hiring new staff.

The development of the wind industry in Spain requires a large workforce with specific skills and qualifications. IRENA estimates that a 50MW onshore and a 500MW offshore (fixed bottom) wind facility require 144,000[69] and 2.1 million[70] person-days, respectively. The 'EU Strategy on Offshore Renewable Energy' identified shortages of skilled and qualified personnel could be a barrier for offshore wind deployment.[71] As such, there is a need to reinforce the training programmes offered at national level, and develop specific training facilities for offshore wind energy, particularly in safety and survival at sea issues. These trainings can be developed in specialised training centres, ensuring they are compatible with international standards in the field.[72]

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[68] AEE (2021). Instalaciones eólicas España 2021.

[69] IRENA (2017), Leveraging local capacity for onshore wind

[70] IRENA (2018), Leveraging local capacity for offshore wind

[71] COM/2020/741 final COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS An EU Strategy to harness the potential of offshore renewable energy for a climate neutral future

[72] Manifiesto por el Desarrollo de la eólica marina en España & AEE (2022), Anuario eólico 2022

Spain has design and engineering capabilities due to the involvement of many of the Spanish engineering companies in the implementation of offshore wind energy projects at an international level. Spanish also has a strong presence of engineering companies in other sectors with synergies, such as in the construction, naval and transport sectors.[73] For example, ICTS-MARHIS[74] research infrastructure offers a unique combination of laboratory, numerical and field facilities providing significant power to solve, design, construct, and exploit aspects of maritime engineering. There is however a growing need in Spain for technical expertise on the offshore installation of electrical substations and substructures for wind turbines.[75]

2.2.5 *Decommissioning and lifetime extension*

With many turbines reaching the end of their design life in the coming years, wind projects have to deal with decommissioning costs and decisions regarding what to do with their assets. BloombergNEF estimates 4 GW of onshore wind power projects reached their 20-25 year lifetime point in 2020 in the world, which by 2030 is expected to reach almost 40 GW.[76] In Spain alone, around 23 GW of wind turbines are expected to reach their end of life by 2023.[77]

In recent years there has been progress in improving the commercial viability of recycling technologies. Current recycling solutions allow for 85-90% of the total mass of a wind turbine to be recycled.[78] There are recycling circuits developed for most of the components (e.g. for steel, cement, copper wire, electronics and gears), however turbine blades are harder to recycle, since they contain complex composite materials. Turbine blades generally contain a combination of reinforced fibres (such as glass- or carbon-fibre) and a polymer matrix to enhance blade performance levels. However, asset owners, turbine makers, academic institutions and recycling companies have been working together to improve the commercial viability of recycling technologies for turbine blades. Vestas recently presented a new solution to recycle epoxy-based turbine blades, a chemical process developed in collaboration with partners of the CETEC project. Epoxy-based resin was prominently used on wind turbine production over the past decades, with the first turbines already reaching their end of operational life. The company will focus on scaling up the novel process into a commercial solution, allowing blade material currently sitting in landfills and in operation to be disassembled and used.[79] ?In the case of Spain, consortium announced their plans to build the first blade recycling plant in Spain (see Textbox 2-4 below).

Moreover, there have been recent technological developments allowing the production of 100% recyclable wind turbine blades, but they are still in the prototype or piloting phase.[80] Siemens Gamesa announced the market launch of the ‘RecyclableBlade’, which will be installed and piloted for the first time in an offshore site at the end of 2022.[81] In March 2022 the Zero wastE Blade ReseArch (ZEBRA) consortium announced the production of their first prototype of its 100% recyclable wind turbine blade .[82] Within the ZEBRA project, LM Wind Power designed and built the world’s largest thermoplastic blade at its Ponferrada plant in Spain.

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[73] Gobierno Español (2021), Hoja de Ruta Eólica Marina y Energías del Mar en España

[74] https://www.ictsmarhis.com/en

[75] AEE (2022). Libro blanco de la industria eólica marina en España.

[76] BloombergNEF(2022). Wind Power in 2020s Must Focus on Capability, Not Cost.

[77] Evwind (2022). Wind turbine blade recycling plant project receives EU recognition.

[78] EurObserv’ER (2022). Wind energy barometer 2022.

[79] Vestas (2023). Vestas unveils circularity solution to end landfill for turbine blades.

[80] EurObserv’ER (2022). Wind Energy Barometer 2022.

[81] Siemens Gamesa (2021). Commanding circularity: Siemens Gamesa announces RecyclableBlade for onshore wind power projects.

[82] GE (2022). Press release: ZEBRA project achieves key milestone with production of the first prototype of its recyclable wind turbine blade.

Textbox 2-4 Construction plans for the first blade recycling plant in Spain. Source: AEE (2022).[83]

In 2022, the consortium created by Endesa, PreZero and Reciclalia Composite, supported by GE Renewable Energy and its subsidiary LM Wind Power announced their plans to build the first wind blade recycling plant in Spain. The plant will have a processing capacity for recycling 2,000 blades per year, accounting for around 6,000 tons of glass-and carbon-fibre. The plant will allow GE Renewable Energy to offer its Spanish-based customers the option to recycle disused blades using the new plant, while LM Wind Power will supply around 50% of the surplus fiberglass generated during blade manufacturing at its plant nearby. The fiberglass will also be recycled to be reused in the construction and ceramics sector, among other applications.

The construction of the plant will start in 2023 and is expected to be operational in early 2024. With a planned investment of 8.5 million euros, the plant will create around 30 direct jobs, together with indirect employment associated with logistic tasks. The project also received a grant of €3.2 million from the Horizon Europe RD&I programme, as part of a larger ‘Blades2Build’ Project. [84]

The project is part of Endesa’s Futur-e plan for the Compostilla industrial complex, in which MITERD and the Regional Government of Castilla y León recently approved 7 projects to create value in the communities where the decarbonisation process is carried out.

Ultimately, the decisions about what to do with these assets are influenced on the regulatory framework and subsidies schemes in place in the location. In Spain there is no regulatory framework on decommissioning wind turbines, and no specific requirements for the treatment of the refurbishment of wind parks.[85] However, Spain’s NECP considers the importance of renewing most of the wind parks in the 2030 horizon and indicates plans for launching specific auctions for repowering/refurbishing installations.[86]

The lack of a value chain for decommissioning wind turbines is a pressing issue for onshore wind energy, while for offshore wind the service will be needed later on. Decommissioning activities of offshore wind projects haven’t been tested in real scenarios, but there are viability studies and decommissioning plans presented in the planning phase of the projects. In theory, these activities would be similar to those carried out in oil and gas platforms, and the treatment of offshore wind turbines will be similar to turbines onshore.[87]

2.2.6 *Enabling factors of the wind power value chain*

Most of the transversal needs and barriers found concern the development of offshore wind projects in Spain, including:

- **Domestic market size** - Currently the Spanish on-shore wind market is small while the offshore wind market is non-existent. This is combined with a lack of stability, visibility and linearity of the market. With regards to Spanish auctions, industry stakeholders consider that the strategy of appealing to technology neutrality policies (where only price is considered, regardless of the technology) as occurred in 2016 and 2017, left wind power in inferior competitive conditions.

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[83] AEE (2022). Endesa y PreZero España construirán la primera planta de reciclaje de palas eólicas de la Península Ibérica con el apoyo de GE Renewable Energy.

[84] Evwind (2022). Wind turbine blade recycling plant project receives EU recognition.

[85] Reglobal (2020). Decommissioning of onshore wind turbines.

[86] AEE (2022), Anuario eólico 2022

[87] AEE (2022). Libro blanco de la industria eólica marina en España.

- **The development of a coherent regulatory framework for onshore and offshore wind** - One of the key challenges of the Spanish wind sector is the **acceleration of administrative processes**. This includes the design of faster permitting processes with reduced complexity. The current speed of administrative processing is deemed too slow, and risks reaching the objectives established in the Spanish PNIEC. According to some industry stakeholders, the average duration of real administrative processing time in Spain to go from 'greenfield' (development stage) to 'Ready-to-Build' is around 7 years for wind farms.[88] Delays in processing administrative requirements such as declarations of environmental impact assessments (DIA) risk projects' access to the grid and their financial guarantees. Moreover, slow permitting processes lead to project deadlines being extended beyond what is foreseen in the government's support schemes. In some cases it means that grants cannot be used, leading to the project's eventual collapse. With this regard, the Spanish wind energy sector calls for both the Government and the Autonomous communities to provide more resources in order to process projects as quickly as possible, thus, allowing the start-up of the necessary facilities. [89] With respect to Offshore Wind, it is urgent to approve the Maritime Spatial Development Plans (POEM) and to update the regulatory framework for offshore wind with an industrial focus, as well as convene offshore wind auctions (see below).
- **Clear pipeline of offshore wind projects** - private investors need have visibility regarding the size of the market in the short and medium term. Other countries, such as the United States and France, have already established how many megawatts are going to be installed yearly between 2024 and 2026, and published a calendar of installations approved by the government. They have aligned their regulations and take steps to achieve this calendar. In Spain there is currently no such timetable, and this is an important barrier for large companies to undertake the necessary investments to set up new factories or expand production capacity. The Spanish wind sector calls for the Government to provide visible schemes that provide certainty to the projects of companies and investors. [90] Moreover, the development of auction mechanism should ideally consider the pipeline of other Member States, so as to avoid competition for the same suppliers & resources.

2.3 Barriers in Spain for the wind power value chain

An overview of the main barriers identified for the development of onshore and offshore wind power value chains in Spain is presented in Table 2-3 below. In the framework of the wind energy value chain analysis, four interviews were conducted, where the perspective of one association and three companies were collected. Overall, the most pressing challenges identified are:

- In the case of wind turbine component manufacturing Spanish industry has been historically well positioned, but currently face significant challenges related to different factors: an **increased competition from Chinese competitors, the establishment of local content requirement in their export markets, and the need for a larger Spanish market for both onshore and offshore**

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[88] Energetica (2022). Habla el sector: entrevistas – Sector: Eolico. Revista de Generación de Energía y Eficiencia Energética. Energética XXI 222 DIC22.

[89] Based on stakeholders interviews, and Energetica (2022). Balance 2022 y Perspectivas 2023: Asociaciones Sectoriales y Otras Organizaciones. Revista de Generación de Energía y Eficiencia Energética. Energética XXI 222 DIC22.

[90] Based on stakeholders interviews, and Energetica (2022). Balance 2022 y Perspectivas 2023: Asociaciones Sectoriales y Otras Organizaciones. Revista de Generación de Energía y Eficiencia Energética. Energética XXI 222 DIC22.

wind. There is also a need to support the national **industrial manufacturing capacity** upstream in order to respond with greater flexibility to the upcoming needs of the market.

- There is a significant **shortage of trained personnel**, and a lot of competition between companies and sectors for securing qualified personnel. Support is needed for the training of professionals in the activities of offshore wind value chain related to construction, installation as well as operations and maintenance to match the expected rise in demand.
- Offshore wind activities need to be included into the planning of the national transport network. Spanish port facilities and services are already very competitive, **however these need to be adapted** to the needs arising from the large-scale development of offshore wind energy. This requires a significant public investment. Moreover, the Spanish State could encourage port authorities to ensure space is provided in the ports to boost the offshore wind sector.
- Finally, one barrier worth mentioning in the context of future value chain needs, related to the establishment of the Spanish industry involved in the decommissioning or recycling of onshore wind turbines. Although this is not considered a current key barrier for the supply chain, with the large number of turbines that will be decommissioned in the coming years, Spain urgently needs to develop the installations for dealing with the management and recycling of components and materials for onshore energy. Under the framework of the Spanish PRTR, there are ongoing programmes providing grants for repowering of wind farms and wind turbine blade recycling facilities (see section 0 for more details on these programmes).

Table 2-3 - Overview of main barriers identified and identified needs for the wind power value chain.

Value chain segment affected	Barriers identified	Needs identified
Manufacturing	• Fierce competition from Chinese suppliers offering much lower prices, increased adoption of local content requirement in export markets, reduced local market in Spain.	• Establish an industrial strategy aligned with the existing supply chain to grow the Spanish wind industry. • Support Spanish upstream manufacturers in order to respond with greater flexibility to the upcoming needs of the market.
Logistics (transport and distribution)	• Adaptations required on Spanish ports to serve the supply chain and logistics associated with offshore wind parks.	• Techno-economic studies of Spanish port infrastructure for the construction, assembly or export of components associated with offshore renewable installations. • Aid programme(grants and loans) to promote and adapt port infrastructure to the development.
Construction and installation and O&M	• Current and future shortage of qualified personnel.	• Support for capacity-building, training and professional qualification in the offshore renewable energy sector.
Decommissioning or life extension	• There is a need to develop a value chain associated with the management and recycling of components and materials for onshore energy, which can be later scaled up to offer services also to offshore wind energy.	• Define a Regulatory framework on decommissioning wind turbines, including setting obligations in tenders for end-of-life handling. • Continue support for RD&I (grants) on recyclable wind turbine components (e.g. turbine blades). • Aid programmes for scaling up facilities recycling onshore wind blades.

2.4 Mapping of existing initiatives related to wind power.

In Spain, there are certain actions associated with the barriers mentioned, developed by MITERD and IDAE in the frame of the PRTR.

- **PERTE EC** [91]: *"PERTE de Economía circular"*. This strategic project seeks to accelerate the transition to a more efficient and sustainable production system, promoting circular economy and industrial competitiveness and sustainability. This PERTE has two lines of action: 1. actions in key sectors: textiles, plastics and capital goods for the renewable energy industry, and 2. transversal actions to promote the circular economy in the company. It includes crosscutting initiatives in different investment measures of the PRTR promoting innovation in eco-design, recycling and sustainability, among other practices to strengthen these initiatives withing the specific sector public calls.
    - MITERD has launched grants, in the frame of the second line, to promote circular economy in companies. Eligible projects must be classified in one the following categories: reduction of the consumption of raw materials, eco-design, waste management improvement and digital transformation of processes to increase efficiency.
- **PERTE ERHA**[92]: *"PERTE de energías renovables, hidrógeno renovable y almacenamiento"*. The goal of this strategic project is to enhance investment in sectors of great relevance as renewable energies, power electronics, hydrogen, and storage. Linked to these strategic projects, some public funding actions have been developed related to certain barriers mentioned. The initiative "*Programas de repotenciación circular*" includes two different programs related to repowering of wind farms, technological and wind turbine blade recycling facilities:
    - **Repowering of wind power plants:** *"Programa 1: Repotenciación de instalaciones eólicas"* [93]. This program supports actions of technological renovation of existing wind farms, replacing wind turbines. These actions imply the dismantling of, at least, the tower, rotor and nacelle of the existing wind turbines affected by the project and the construction and commissioning of new wind turbines on site.

    - **Wind turbine blades recycling**: "*Programa 3: Instalaciones innovadoras de reciclaje de palas de aerogeneradores*" [94]. The third program of this initiative is focused on innovative wind turbine blade recycling facilities, one of the areas foreseen in Action line 1 of PERTE EC. The objective is to incentivize the development of effective and efficient recycling techniques with circular economy criteria for blades.

In the frame of PERTE ERHA, another relevant initiative is "*Programa Renmarinas Demos*", supporting the following actions through four different subprograms: creation and reinforcement of test platforms for offshore wind as well as the development of technology demonstrator linked to test platforms.

- **Testing platforms for offshore wind:** "*Subprogramas 1 y 2: Creación o refuerzo de plataformas de ensayo para renovables marinas*" [95]. These programs support the creation or reinforcement of infrastructure for testing, demonstration and validation of prototypes and

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[91] PERTE EC. https://planderecuperacion.gob.es/como-acceder-a-los-fondos/pertes/perte-de-economia-circular

[92] PERTA ERHA. https://planderecuperacion.gob.es/como-acceder-a-los-fondos/pertes/perte-de-energias-renovables-hidrogeno-renovable-y-almacenamiento

[93] Programa 1: Repotenciación de instalaciones eólicas. https://www.idae.es/ayudas-y-financiacion/programas-de-repotenciacion-circular

[94] Programa 3: Instalaciones innovadoras de reciclaje de palas de aerogeneradores. https://www.idae.es/ayudas-y-financiacion/programas-de-repotenciacion-circular

[95] Subprogramas 1 y 2(Renmarinas Demos). https://www.idae.es/ayudas-y-financiacion/programa-renmarinas-demos

innovative devices of pre-commercial projects related to offshore wind inside or outside port infrastructures within the national maritime-terrestrial domain.

- **Technology demonstrators:** "*Subprograma 3: Desarrollo de demostradores tecnológicos renovables marinos y Subprograma 4: Demostradores tecnológicos renovables marinos ligados a una plataforma de ensayos*" [96]. The third subprogram of Renmarinas Demos covers the development and experimental tests in the demonstration and validation of prototypes related to different areas such as floating or fixed foundation technology for wind turbines and hybrid technology between offshore wind and other renewable energies. Projects that combine the creation of testing platforms linked to technology demonstrators are also eligible for financing, as stated in the fourth subprogram.

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[96] Subprogramas 3 y 4 (Renmarinas Demos). https://www.idae.es/ayudas-y-financiacion/programa-renmarinas-demos

3 Solar PV

Solar PV in Spain in 2021 was responsible for 10% of the produced electricity (26 TWh), almost doubling its production from the 2018 level and a 5.3 TWh increase compared to 2020. Especially since 2019 annual capacity additions have been large, in contrast with the period between 2013 and 2019 where annual production virtually stagnated, mainly due to a lack of financing and government support for the sector. As a result, installed capacity in 2021 was 15 GW, the 2nd highest of the EU (after Germany).[97]

Due to its very suitable climate conditions with high irradiation and low cloud cover, Spain has the potential to fulfil a large share of its electricity use in 2050 through solar PV at relatively low costs and hence subsidy levels. The national government of Spain foresees a significant role for solar PV in achieving its objective of a 100% renewable electricity system in 2050. As an intermediate goal, Spain aims to extend its installed capacity to at least 39 GW in 2030.[98]

For this high-level assessment report, the value chain of solar PV technology has been investigated to identify the most relevant barriers and needs on the road towards climate neutrality in 2050. We focus on the value chain for the currently most widely used PV panels using (mono)crystalline polysilicon (c-Si) cells (>95% global market share in 2021), which are expected to remain dominant in the near future.[99]

3.1 Solar PV value chain at EU level

We identify the following main components of the solar PV value chain:

1. **Sourcing of raw materials and compounds –** The main elements necessary to produce c-Si PV panels (later referred to simply as 'panels) in terms of value are crystalline silicon (only 3% of weight but 35-45% of total value in 2021), silver (9-23% of value), glass (11-15%), aluminum (9-12%), copper (5-12%), polymers (7-10%), followed by smaller shares of tin, zinc, and lead. Raw materials and compounds used for producing other necessary equipment, such as inverters and racking, mostly use materials such as steel and aluminum.
2. **Manufacturing of equipment and compounds –** The necessary equipment and compounds needed for a solar PV generation plant can be grouped in several parts. The costs of the PV module can form up to 50% of the initial investment costs depending on other cost components and are therefore one of the major cost elements.[100]

   The panel manufacturing process consists of 5 main sequential stages: polysilicon production, ingots, wafers, cells and finally panel/module assembly. More than 80% of global production capacity in all stages is concentrated in China. Next to the modules, other equipment and compounds necessary are the inverters (5% of investment cost**Error! Bookmark not defined.**) and racking/frame (6%).

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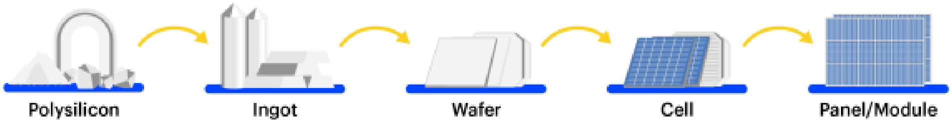
[97] ENTSO-E(2022). Transparency Platform.
[98] Spain NECP (2021): https://energy.ec.europa.eu/system/files/2020-06/es_final_necp_main_en_0.pdf
[99] IEA (2022). Special Report on Solar PV Global Supply Chains
[100] IEA (2020). Utility-scale PV investment cost structure by component and by commodity breakdown. Initial investment costs and associated financing costs are 80-90% of LCOE of solar PV.

Figure 3-1 Key stages in the manufacturing process for solar PV. Source: IEA (2020)



Besides the manufacturing process, the equipment needed for production is of strategic importance in the value chain. Especially equipment for the last 2 steps (from wafer to cell and from cell to module), since these make up 70% of the sales value of modules. **Error! Bookmark not defined.** While in the past equipment manufacturing was spread out over Europe, the US and China, currently China has a 45% market share.[101]

3. **Logistics (transport and distribution)** - costs for solar PV only form a minor part of total investment costs (<1%), also compared with other renewable technologies (~6% for onshore wind). Similar to other technologies, good infrastructure is necessary to transport PV panels, including access to ports and road infrastructure to ship modules and other components. However, reflected by the low cost, transport for PV panels is relatively straightforward and does not require any specialized transport or distribution solutions.
4. **Construction and installation** – According to the IEA, installation costs for utility-scale PV can reach up to 20% of initial investment costs for solar PV. For residential PV, costs are significantly higher. Costs can be divided in electrical installation (grid connection, wiring), mechanical installation (installing the racking, civil works) and inspection (testing and commissioning).[102] Installation costs are logically highly depending on local labour cost levels and labour availability.
5. **Operations and Maintenance** - Operations and Maintenance (O&M) costs are relatively low for solar PV, ranging up to 10% of total LCOE costs and 10 EUR/kW.[103] Preventive maintenance, repairs and module cleaning form the majority of costs. Some components, such as inverters, are also replaced during the lifetime of a PV installation, which is 25-30 years.[104] Similar to construction and installation, labour costs form a large share of the costs and are hence dependent on labour availability and wage levels.
6. **Decommissioning or life extension** – with ever more PV panels in the coming years reaching the end of their lifetime, decommissioning and/or life extension become an ever more relevant topic. IEA expects decommissioned panel capacity to grow from 7 GW in 2030 to 200 GW in 2040 – an almost 30x increase. Taking into account continuing growth of solar PV, recycling could deliver about 20% of the raw material demand for panels in 2050 for aluminium, copper and glass; for silicon it could be 35% and silver even 60%, taking into account current trends towards lower material use per panel of these materials.[105] In this way, improved recycling could reduce the resource dependency of the EU. However, recycling is complex and its use depends on existing regulation; in the EU the recycling rate is 95% while in the US it is only 10%.

Textbox 3-1 presents a cost breakdown of the production of utility-scale PV.

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[101] IEA (2022). Special Report on Solar PV Global Supply Chains

[102] IRENA (2021). Renewable Power Generation Costs 2021.

[103] ibid.

[104] IEA (2022). Special Report on Solar PV Global Supply Chains.

[105] KU Leuven (2022). Metals for clean energy.

Textbox 3-1 Cost breakdown of utility-scale PV

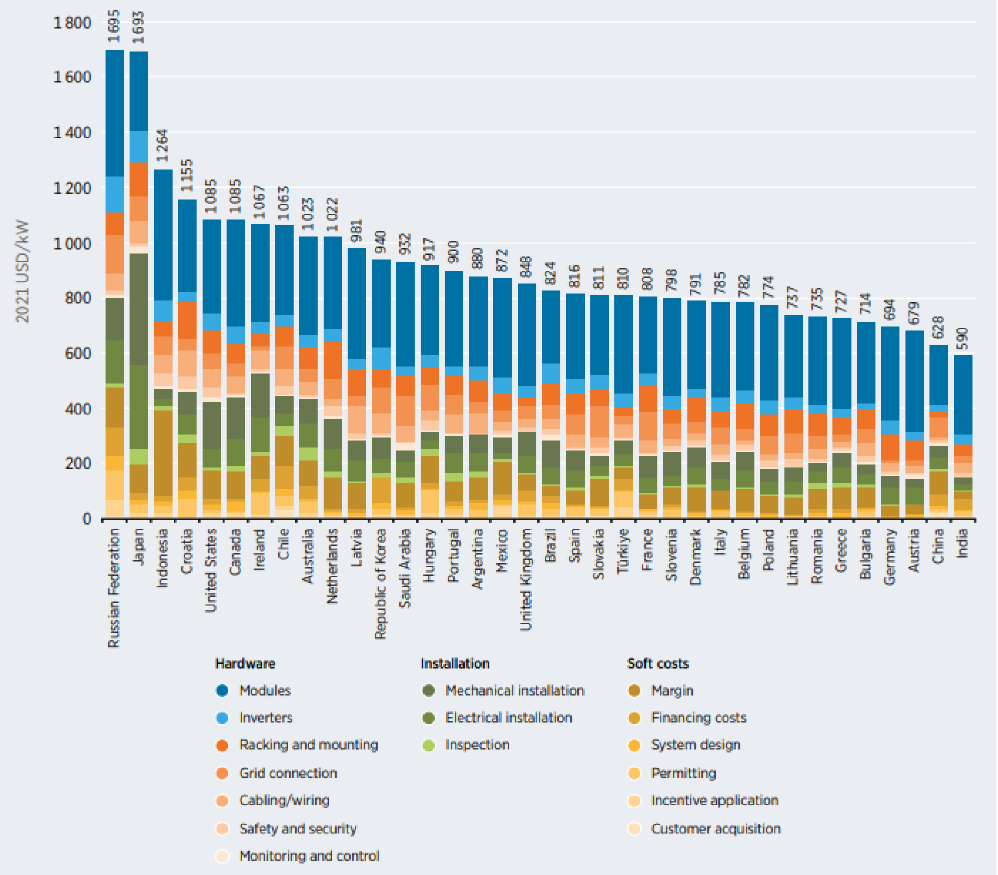
IRENA has published data in 2021 on the costs of utility-scale PV (Figure 3-2). In the figure one can see that the **module and inverter costs** in the top 10 markets make up between 24-54% of total installed costs; since operational costs are a relatively low part of the total costs of solar PV, total installed costs give a very good indication of total project costs. Module and inverter costs are also comparable in costs between countries and cost differences mainly arise from differences in other cost components. Costs in Spain are 816 USD/MW in 2021, comparable to other EU countries. On the other hand, due to its high solar irradiation, PV panels in Spain can achieve more full load hours than in most EU countries. This results in a higher annual electricity production per panel and subsequently a lower LCOE than in other regions.

Balance of System (BoS; construction) costs are 10-20% of installed costs and include the costs for racking, grid connection, cabling/wiring, safety and security and monitoring. Large cost differences are observed in installation costs (mechanical and electrical installation and inspection) mainly due to different labour costs.

Soft costs, such as margins for the project developer, financing costs, permitting, customer acquisition are between 5-20% of installed costs, with the profit margin being the largest part of this cost component in most countries.

Costs for households and **rooftop PV** are higher than for utility-scale PV. Higher installed costs are mainly the result of higher soft costs (margin, grid connection/fees, sales tax).[106]

Figure 3-2 Cost breakdown of installed costs of utility-scale PV in main markets. Source: IRENA (2021)[107]



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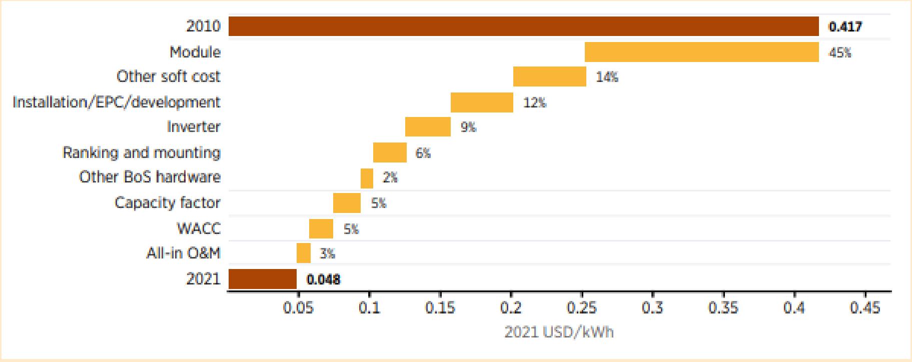
[106] NREL (2022). Costs Continue to Fall for Residential, Commercial, and Utility-Scale Solar and Energy Storage Systems

[107] IRENA (2021). Renewable Power Generation Costs 2021.

Between 2009 and 2021 the LCOE of solar PV decreased massively (88%-95%). This impressive cost reduction was mostly the result of reductions in module costs. As a consequence, in the current cost breakdown non-module costs become ever more important for project costs. Other cost reductions were achieved through lower soft costs (especially lower financing costs due to a more mature market), installation costs (through learning), lower inverter costs and other drivers.

Figure 3-3 Drivers of the decline of LCOE of utility-scale solar PV. Source: IRENA (2021).[108]



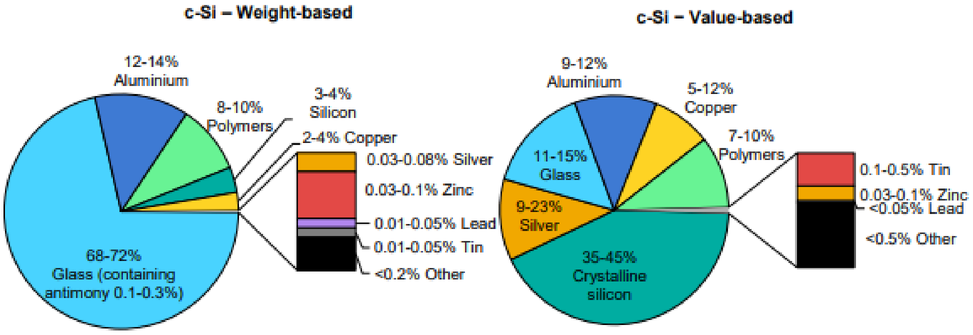
3.2 Mapping the solar PV value chain and barriers

In this section we will discuss all steps in the value chain and the potential challenges and needs for Spain and the EU.

3.2.1 *Sourcing of raw materials and compounds*

Figure 3-4 shows the main materials used for crystalline silicon PV panels. In general, most components used for PV are common and global supply is diversified. Most critical is the production of high-quality crystalline silicon, which forms 40% of the raw material value of PV panels.

Figure 3-4 Material composition shares of crystalline silicon PV modules by weight and average value, 2021. Source: IEA (2022)[109].



A recent Trinomics study[110] as well as the EU CRM list[111] identifies antimony as having moderate vulnerability; silver is identified as well in the Trinomics study. Furthermore, a recent analysis of +Trinomics has mapped the value chain of solar PV and its vulnerable elements based on import

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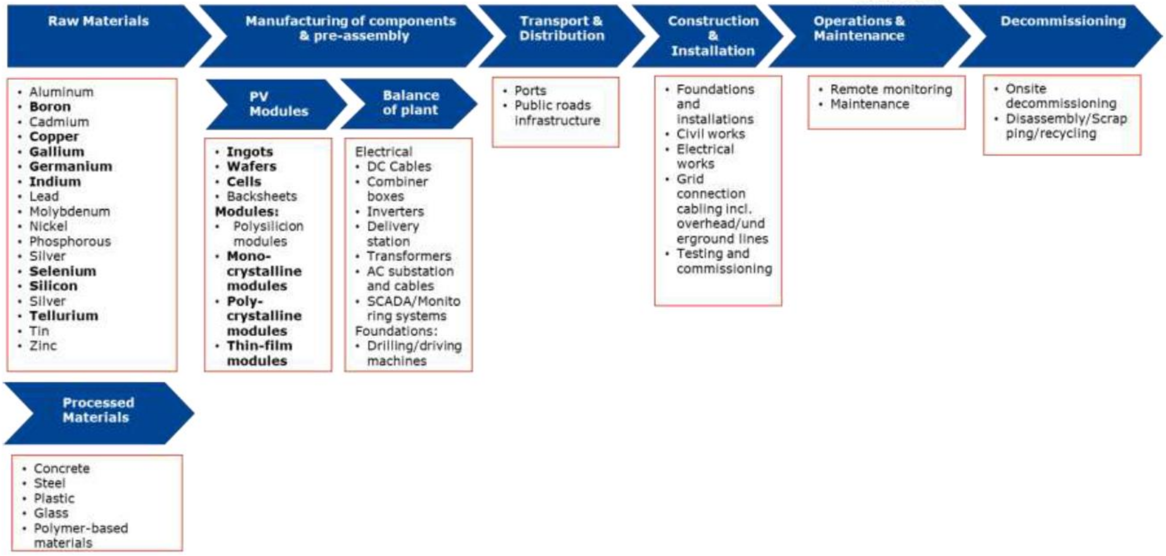
[108] IRENA (2021). Renewable Power Generation Costs 2021.
[109] IEA (2022). Special Report on Solar PV Supply Chains. Available at: https://iea.blob.core.windows.net/assets/d2ee601d-6b1a-4cd2-a0e8-db02dc64332c/SpecialReportonSolarPVGlobalSupplyChains.pdf
[110] Trinomics (2022). RepowerEU (unpublished yet).
[111] EC (2020). EU Critical Raw Materials List 2020.

dependency, market concentration, substitutability and price stability.[112] In contrast to other technologies (with several vulnerable elements throughout the supply chain (such as wind), this study found limited vulnerabilities and most materials with vulnerability are used in thin-film modules, which form only 5% of currently produced panels. Hence, for the dominant monocrystalline modules, raw material is not a critical bottleneck or vulnerability for future production with solar PV only requiring small volumes compared with total global supply of these materials. However, material processing is significantly more critical, which will be discussed in the next section.

Figure 3-5 Overview the solar PV supply chain. Vulnerable elements are in bold. Source: Trinomics (2021)[113]



Note that the figure both shows vulnerable elements for silicon and thin-film panels.

Crystalline silicon is acquired through processing silica (quartz) — a globally abundant material — at high heat with a carbon source; a process that has a high energy-intensity. 70% of global silicon production is located in China.[114] Besides China, the EU is still a large supplier of silicon (mainly Germany). Lead times for silicon production are between 3-5 years, which is the longest of all production steps of PV panels, but still significantly lower than lead times for new mining projects. The abundance of the raw material for silicon (quartz) and the lack of mining are factors that make it easier to diversify production than for other materials (mainly metals). Still, current dependence on China is large and has grown significantly in the past 10 years.

Other raw materials for panels and for other equipment and compounds (such as inverters, racking/frame and installation) shows lower vulnerabilities.

To conclude, raw material supply for solar PV at least in the short term is no major barrier globally and in Spain - especially when compared with other technology supply chains – but it could potentially become a significant barrier in the future. This view was confirmed by several interviewees of sector associations. Additionally, main materials such as silver and aluminium are currently not extracted in Spain and reserves are limited, thereby offering no significant opportunity for local production (not considering

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[112] Trinomics & Artelys (2021). Study on the resilience of critical supply chains.

[113] Trinomics (2021), Study on the resilience of critical supply chains for energy security and clean energy transition during and after the COVID-19 crisis

[114] USGS (2022). Mineral commodities Summary

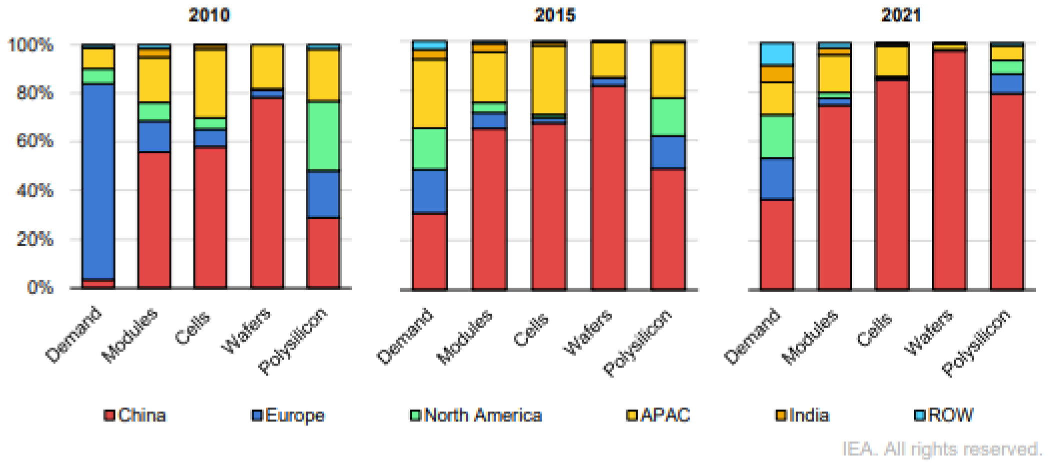
environmental factors). The role of Spain is very limited in this regard without specific opportunities for Spain, though it is important to address any criticalities on an EU-level.

Raw material use could also be further reduced by decreasing the material intensity needed in panels or extending the lifetime of panels. To give two examples, polysilicon intensity has reduced by a factor six between 2004 and 2020, while silver intensity decreased threefold.[115] Also, alternative materials with similar characteristics could be used in panels to diversify material needs. This is not done in measurable quantities yet though, and it will likely not happen in absence of significant price increases or regulatory measures.

3.2.2 Manufacturing of equipment and compounds

Most new additional manufacturing capacity for PV has been realized in China. As a consequence, more than 80% of global capacity for all production stages is currently in China (see Figure 3-6), most notably the Xinjiang region. Even more extreme is that 97% of all ingot production is concentrated in China. The relative dependence on China has significantly grown since 2010, along with the growth of the PV sector. Most competition for the production of cells and modules comes from other Asian-Pacific countries such as Vietnam, Malaysia, and Thailand. The role of EU production is hence on a global scale very limited in all stages. One of the explanations for this growing dominance of China is that solar policy has always been aimed at not only stimulating demand but also subsidizing local supply, while policies in the EU and Spain have been aimed at the demand-side only.

Figure 3-6 Manufacturing capacity of silicon PV panels by country and region. Source: IEA (2022)[116]. Special Report on Solar PV Supply Chains.



APAC = Asia-Pacific, ROW = Rest of World.

This very high dependence of Spain and the EU on China leads not only to a missed economic opportunity for the EU and Spain, but also means a high dependence on China and creates the risk of a major supply disruption in case of export restrictions. This was confirmed as a significant barrier in the interviews. The risk of a possible export restriction has become a more realistic scenario in light of the current tensions between mainly the US and China with some trade restrictions in place on Chinese panels to the US.[117] On

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[115] IEA (2022). Special Report on Solar PV Global Supply Chains

[116] IEA (2022). Special Report on Solar PV Supply Chains. Available at: https://iea.blob.core.windows.net/assets/d2ee601d-6b1a-4cd2-a0e8-db02dc64332c/SpecialReportonSolarPVGlobalSupplyChains.pdf

[117] S&P Global (2022). Solar market braces for new US trade restriction on China & Bloomberg (2023). China Mulls Protecting Solar Tech Dominance With Export Ban

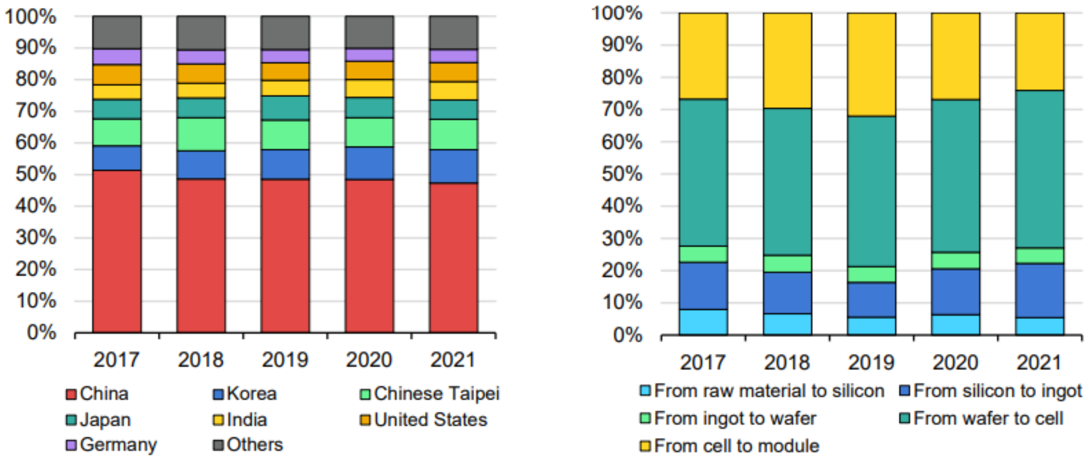
the long-term, trade barriers are aimed at promoting local production of components and hence reduce dependency. On the short-term however, trade barriers — and the response of countries such as China – could lead to reduced quantities or more expensive PV module prices and make the dependency visible.

The lack of supply diversification and dependence on China can also lead to volatile prices for PV panel components. While there is overcapacity for most stages in the supply chain, global polysilicon production capacity is currently a bottleneck, which resulted in a quadrupling of polysilicon prices between 2020 and 2022. The main reason for this is that lead times for new polysilicon production capacity are the longest of all manufacturing steps (3-5 years), which makes it difficult to adjust production to rapid changes (i.e. increases) in demand, such as in 2021 during Covid recovery. Diversification of supply could partially mitigate this price uncertainty.

The EU has presented intentions to build up local manufacturing capacity, through its EU Solar strategy presented in May 2022 and the subsequent European Solar PV Industry Alliance.[118] In addition, there are several PV projects in the EU that are supported through the Important Project of Common European Interest (IPCEI) framework.[119] Furthermore, recent developments in the EU industrial strategy include loosening state-aid rules for manufacturing industry and permitting rules.[120]

There is potential to further scale up production in the EU in Spain and there are still some (small) suppliers in the EU and Spain. A potential first and important step into bringing production back to the EU would be investing in **manufacturing** equipment and associated knowledge, given its strategic importance and being technically the most complex equipment needed to set up a European supply chain. Hence, building up equipment manufacturing is a good way to build up the technical capacity needed to also grow production of other stages in the production chain.

Figure 3-7 Manufacturing equipment revenue based on region (left) and value (right).



Source: IEA (2022). *Special Report on Solar PV Global Supply Chains*

Also, silicon panels are reaching their technical and cost limits, which creates opportunities for new panels that can reach higher efficiencies, such as tandem panels combining two types of solar cells (e.g. silicon and perovskite). These use cases will likely stay 'niche' and only preferential in specific cases in

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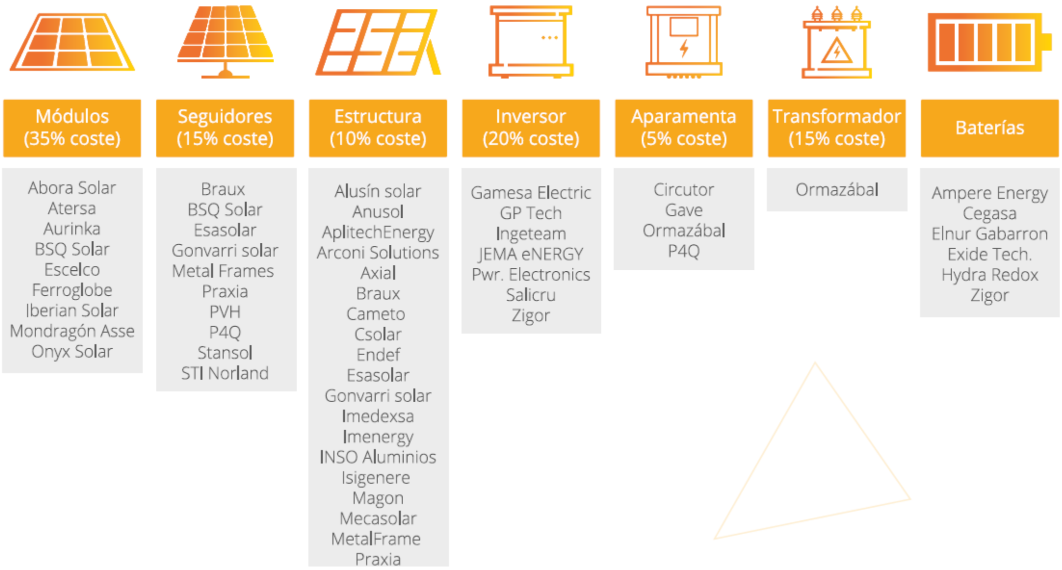
[118] EC (2022). EU Solar Energy strategy & RePowerEU Solar Industry Alliance.
[119] ESMC (2022). IPCEI for PV launched in Brussels.
[120] Reuters (2023). EU pledges wind and solar funding, narrow gap with US.

the near future. For example, tandem panels could be particularly interesting in locations and regions with limited space, where the higher efficiency per surface outweighs the additional costs. Additionally, there could be additional possibilities; for example, Spanish company Onyx is one of the leading manufacturers of transparent PV in glass for buildings.

In Spain, there are some existing manufacturers in the manufacturing chain Figure 3-8, including final module production, though on a very limited scale. Recent announcements of large-scale production of Solar PV modules include the construction of a 5 GW production of monocrystalline silicon wafers for PERC cells in Seville by the Spanish start-up Greenland, in collaboration with Fraunhofer Institute (ISE) and Bosch.[121]

Next to the PV panels, for other equipment Spain (and the EU) also has a higher global market share. Most notably, there are several Spanish inverter and solar tracker producers.[122] Power Electronics, a Spanish inverter manufacturer, is one of the two largest EU players in this segment (together with German producer SMA). However, recent trend reveals that both Power Electronics and SMA, have grown less than other companies in China, loosing competitiveness in 2021. This change comes after a three year period of having a considerable share in the inverter market. Moreover, the EU (and Spain) is dependent on imports for the chips needed for the production of inverters.[123]

Figure 3-8 Overview of main Spanish companies active in all stages of the solar PV supply chain. Source: UNEF (2022). Energia Solar informe annual 2022.



Módulos (35% coste)	Seguidores (15% coste)	Estructura (10% coste)	Inversor (20% coste)	Aparamenta (5% coste)	Transformador (15% coste)	Baterías
Abora Solar Atersa Aurinka BSQ Solar Escelco Ferroglobe Iberian Solar Mondragón Asse Onyx Solar	Braux BSQ Solar Esasolar Gonvarri solar Metal Frames Praxia PVH P4Q Stansol STI Norland	Alusín solar Anusol AplitechEnergy Arconi Solutions Axial Braux Cameto Csolar Endef Esasolar Gonvarri solar Imedexsa Imenergy INSO Aluminios Isigenere Magon Mecasolar MetalFrame Praxia	Gamesa Electric GP Tech Ingeteam JEMA eNERGY Pwr. Electronics Salicru Zigor	Circutor Gave Ormazábal P4Q	Ormazábal	Ampere Energy Cegasa Elnur Gabarron Exide Tech. Hydra Redox Zigor

3.2.3 *Logistics (transport and distribution)*

PV panel shipping and transport to production locations is relatively simple, given the low weight and modularity of PV components in comparison to other clean energy technologies (e.g. wind turbines). Transportation accounts for less than 3% of total production emissions of panels.[124] Among others, PV

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[121] Carrara, S. et al. (2023). Supply chain analysis and material demand forecast in strategic technologies and sectors in the EU – A foresight study, EUR 31437 EN, Publications Office of the European Union, Luxembourg, 2023, ISBN 978-92-68-00407-4, doi:10.2760/334074, JRC132889.

[122] UNEF (2021). Energia Solar. Apuesta Segura para recuperacion economica.

[123] Carrara, S. et al. (2023). Supply chain analysis and material demand forecast in strategic technologies and sectors in the EU – A foresight study, EUR 31437 EN, Publications Office of the European Union, Luxembourg, 2023, ISBN 978-92-68-00407-4, doi:10.2760/334074, JRC132889.

[124] IEA (2022). Special Report on Solar PV Global Supply Chains

panel shipping is influenced by general global shipping developments and there are no identified technology-specific considerations. As a result, no *additional* barriers compared with other 'common' technologies could be identified for Spain. This conclusion is supported by the RESmonitor survey for Spain.[125]

3.2.4 Construction, installation and O&M

Renewable energy technology generally speaking are more labour-intensive than fossil alternatives. Even more so, it is estimated that on average solar PV has the highest labour intensity per GWh energy-output of all energy technologies.[126] This is both the case for the manufacturing stages as well as the localized O&M, installation and construction tasks. In the EU, currently 79% of solar jobs are in the deployment (installation and construction) stages, while less than 10% of the jobs can be found in manufacturing and O&M.[127] Hence, labour needs in Spain will be largest in the deployment stage (excluding potentially building up local manufacturing capacity).

Sector interviews also show that labour shortages are a barrier already in some segments and could become a barrier on the short-term in others. Most notably, there currently is a lack of installers seriously limiting the rollout of mainly rooftop and small-scale PV.

Labour intensity of rooftop PV is higher than for utility scale PV. Spain historically has a high percentage of utility scale PV and 60% of solar jobs in 2021 were in utility-scale systems. In response to the current energy crisis, Spain has especially increased its ambitions for rooftop PV. Quick scale up of rooftop PV capacity could result in a higher labour intensity per produced energy-unit. This further increases the need for ample skilled labour to make the fast upscaling of (rooftop) PV in Spain possible. Similar to other labour adjustments, vocational training combined with reskilling of displaced workers could help improve the labour pool for solar jobs.

Moreover, in case Spanish companies extend their activities in manufacturing, that will further increase the need for skilled labour. Though not analysed in-depth, there seems to be limited overlap between the needed skills for panel manufacturing and installation.[128]

A lack of sufficient skilled labour is a wider barrier for the transition towards climate neutrality and is not unique to solar PV. Therefore, a broader approach taking into account the restructuring needed for the whole transition is preferred. The National Energy and Climate Plan of Spain in 2021 already identifies this need for training sufficient professionals to enable the transition to net zero in 2050.[129]

3.2.5 Decommissioning and lifetime extension

Recycling and reuse after decommissioning becomes ever more important with the continuing global growth of solar PV. In addition, extending the lifetime of panels can reduce material requirements per produced energy unit. Additionally, other components such as inverters and racking, could be potentially reused after the panels lifetimes. Enabling high quality and easy reuse of panel components starts at the design of panels. Therefore, there are opportunities to improve the design for better decommissioning

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[125] RESmonitor (2022). Spain

[126] IMF (2022). Jobs Impact of Green Energy, though more research is needed to confirm these findings.

[127] Solarpower Europe (2022). EU Solar Jobs Report 2022

[128] IEA (2022). World Energy Employment.

[129] Spanish Government (2021). NECP 2021. Measure 2.14.

and reuse, for example easier removal of glass from solar cells.[130] In addition, the continuing trend of decreasing material intensity (e.g. silicon, silver) leads to less waste per produced energy unit. Also, increased domestic material reuse could partially alleviate energy security concerns.

Recycling currently mostly happens locally. While recycling rates are high in the EU due to regulatory obligations, it is still expensive. Advancements in recycling technology could increase the market value of the recycled product and/or reduce the recycling costs. The end-of-life stage where panels and other components can be reused, repurposed and recycled starts at the solar plant location. In Spain and the EU, recycling is mainly focused on reusing the raw materials, but not focused on these higher grades of reuse.

It is important not to overstate the potential short-term impact of better recycling and reuse. Due to the steep continuous increase in installed PV capacity – both in Spain and globally – recycling at the end-of-life after 20-30 years can only in the far future provide an alternative for new materials on a large scale. On the other hand, old panels because of their significantly higher material intensity, also contain more materials to be recycled. The IEA estimates that in the period 2030-2040 module recycling can contribute up to 5% of the material requirements and only from 2040 and onwards this increases to 20 to 60% (silver has highest share due to recent improvements in material intensity).

In Spain, recycling sooner could have an impact, because of the high installed capacity of old panels (pre-2011) with high material intensity that will reach their end of life sooner. From a long-term perspective, it is still recommendable to improve panel recycling to reduce material use also after 2040. The need here is twofold: a) start thinking now on end-of-life decommissioning and design requirements for panels, since this will influence recyclability in 20-30 years (for example through Ecodesign requirements. B) improve the current business case for recycling and improve recycling potential through RD&I to achieve modest but important material savings on the shorter term.

3.2.6 *Enabling factors of the Solar PV value chain*

It is worthwhile to stress that in this study the focus is on the solar PV value chain segments. Outside of this value chain, there are enabling factors that currently hinder the fast upscaling of solar PV and consuming PV-generated electricity by businesses and households. Moreover, literature review and interviews show that some of the largest challenges are regulatory and relate to a lack of incentives in the current electricity market framework for renewable generation. Interviewees mentioned a lack of incentives for storage and also barriers to delivering surplus solar PV to the grid, thereby making the business case for PV installations less attractive. Also, after solar-hindering policies between 2011 and 2018, stable policy going into the future is needed for a stable sector in Spain. Other main challenges are timely expansion of the electricity grid which requires massive new and timely investments as well as significant labour at grid operators.

More specifically, other reports such as the RESmonitor[131] for Spain mention the slow permitting processes and related time-consuming environmental impact assessments as barriers, though recently measures to shorten permitting processes have been taken.[132] Since these barriers are not specifically connected to the value chain and hence scope of this report, we will not go in detail on all these aspects. Also, measures

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[130] Mark Peplow (2022). Solar panels face recycling challenge

[131] RESmonitor (2022). Spain

[132] Reuters (2022). Spain's solar permit changes pose fresh size, siting questions

are taken on Spanish and EU level to address these other barriers; RePowerEU for example aims to speed up -where possible – permitting processes for solar and other technologies.

3.3 Barriers in Spain for the solar PV value chain

Below table shows the main identified barriers for solar PV. In most cases - and especially the sourcing of materials and manufacturing steps - an EU-wide approach and at least alignment is advised. Implementation, such as the training of skilled workers, can better be done tailor-made on local level.[133] Before going into barriers, it is worthwhile to note that the interviews sketch an overall positive picture of the development of the solar PV sector in Spain with several positive developments, both in terms of financial support, solid regulatory improvements and the political will to further expand the solar PV sector in Spain. This stands in contrast to the period between 2011 and 2018 when solar PV in Spain stagnated immensely. This pro-climate political and economic environment also provides a chance to create the necessary framework to improve the Spanish solar PV sector.

Table 3-1 Overview of main barriers identified and identified needs for the solar PV value chain.

Value Chain segment affected	Barriers identified	Needs identified
Sourcing of materials and components	Moderate: large dependence on other regions and high market concentration for silicon. However, Spain and EU have potential for own production within 5 years for silicon.	• Further investigate need to scale up silicon production capacity in EU. • Spain has potential for silicon production, but long lead time to start production.
Manufacturing	Very high market concentration (>80%) on China in all steps of the manufacturing process of modules.	• Explore need to build up manufacturing capacity in some key manufacturing steps, although not all steps are critical according to interviews, preferably cooperating through an EU-level strategy. • Support local manufacturing through design standards, such as on modularity, recyclability, lifetime, or even socio-economic impact.
Logistics	No large barriers identified, except dependence on global shipping (which is no different than for other imported products).	
Construction and installation + O&M	Lack of skilled labour, also on the short-term (also for manufacturing possibly). Slow permitting procedures.	• Invest in retraining of personnel and promotional programs to attract future workforce. • Aim to further improve permitting, while not at the cost of rigor, though first steps have been made recently through e.g. simplifying environmental permitting.[134]
Decommissioning or life extension	There is a need to further develop the recycling value chain, especially aimed at higher grade reuse and reducing recycling costs.	• Build up high-quality recycling capacity before first wave of PV reaches end of lifetime around 2030. • Set obligations in tenders for end-of-life handling.
Transversal	Regulatory barriers in the Spanish electricity market model, including a lack of incentives for storage.	• According to sector interviewees, main needs are regulatory and not financial. • Improve grid access for solar PV projects, through large investments in the grid, on the short term stimulate efficient use of existing grid among others through regulatory improvements, such as capacity mechanisms or non-firm capacity contracts. Increase cross-border connections with France/Morocco.

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[133] RESmonitor (2022). Spain

[134] Ministry for the Ecological Transition (2023). Zonificación ambiental para energías renovables: Eólica y Fotovoltaica

3.4 Mapping of existing initiatives related to Solar PV.

In the field of Solar PV, some initiatives launched by MITERD and IDAE have been identified:

- **Self-consumption**: "*Autoconsumo y al almacenamiento, con fuentes de energía renovable*" [135]. This initiative supports the implementation of self-consumption facilities, with renewable energy sources. However, the main objective of this program is not linked to the barriers listed in this section, as grants are given to increase the demand of this sort of facilities.
- Other programs launched by IDAE, such as "DUS 5000" or "Comunidades Energéticas" offer financial support for similar actions (i.e. renewable electricity generation facilities for self-consumption or substitution of conventional energy for sustainable energy) especially supporting the demand side.

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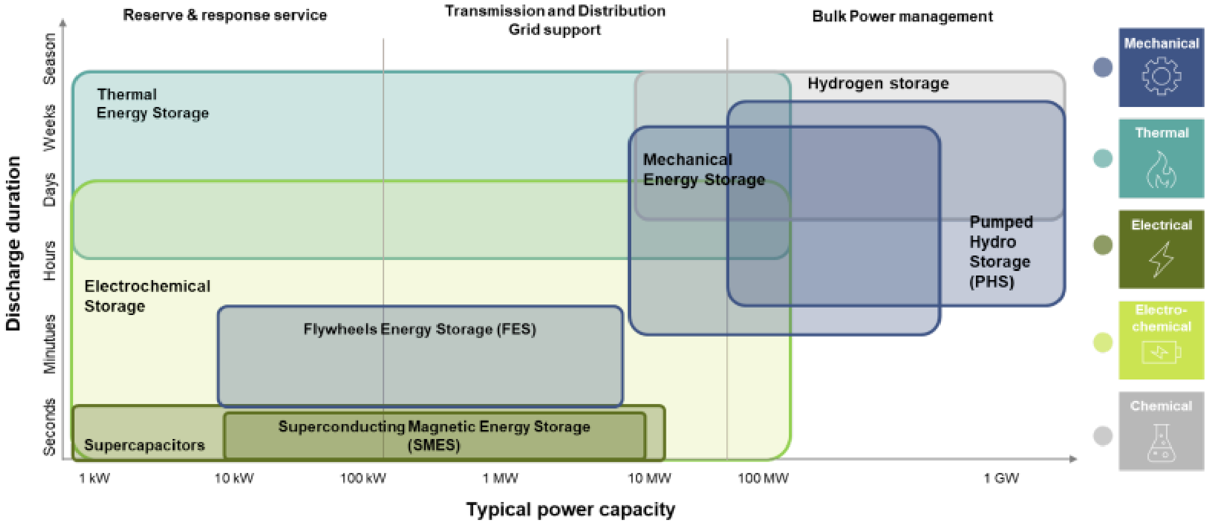
[135] Autoconsumo y al almacenamiento, con fuentes de energía renovable. https://www.idae.es/ayudas-y-financiacion/para-energias-renovables-en-autoconsumo-almacenamiento-y-termicas-sector/incentivos-autoconsumo-y-almacenamiento-con-fuentes-de-energias-renovables-rd-4772021

4 Energy Storage

Energy storage refers here to any technology that stores energy either to use/release the energy later, or possibly to transport this energy to another location for use. When used at a later time, the energy is generally released as electricity, and it is commonly generated from thermal, chemical, electrochemical, electrical, or mechanical reservoirs.[136]

Figure 4-1 Typical power capacity and discharge duration of common energy storage technologies. Source: EASE (2022)[137]



Thermal energy storage saves energy as heat. Electricity or other energy inputs can be used to generate the heat, and the heat can be used directly later or can be converted to electricity. The most common thermal storage technology for power systems is molten salts, which use high-temperature salts, both via phase change from solids and via temperature increases to store thermal energy.

Chemical energy storage refers to those that store energy via bonds between molecules and atoms. An example of this is hydrogen electrolysis, which produces hydrogen and oxygen from water. The oxygen is released into the atmosphere, while the hydrogen is stored. Later, this hydrogen is combined with oxygen to produce water within a fuel cell, releasing both heat and electrical energy. Hydrogen forms an important part of the future energy strategy of the EU it and plays a very large role in Spain's energy strategy as well. This topic is further discussed in the Hydrogen section (Section 4).

Electrochemical energy storage relies on chemical reactions to store energy as electrical potential within a medium. The most common technology here are batteries. Lead-acid batteries are a mature technology with common use across the electricity domain. Lithium-ion batteries are a mature technology at smaller scales (e.g. consumer electronics) and are reaching more widespread use at larger scales (i.e. for grid storage and electric mobility applications). Flow batteries are a less mature technology based on a hybrid use of battery and fuel-cell technologies that store energy within electrolytes.

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[136] MITECO (2021), ESTRATEGIA DE ALMACENAMIENTO ENERGÉTICO

[137] EASE (2022), Energy Storage Targets 2030 and 2050.

Electrical energy storage uses electrical or magnetic fields to store energy. Capacitors and inductors store energy in this way, and their near-instantaneous response and tiny storage volumes make them ideal for use in electronics. They are also used in power systems at larger scales for very-short-term balancing.

Mechanical energy storage uses mechanical processes to store energy, generally as potential or kinetic energy. These devices include flywheels (storing energy as the angular momentum of a heavy wheel), pumped hydro (storing energy via pumping water to higher and lower elevations), and compressed air/other gasses (saving energy as increased pressure of a gas). Flywheels generally can respond rapidly to energy requirements but usually store little energy, while pumped hydro and compressed air take more time to output or input energy. These mechanical stores are very often converted to and from electricity.

These energy storage technologies are expected to be used at different amounts in the future energy landscape. Most EU-wide estimations place the need for energy storage by 2030 at about 100-120 GW of capacity. However, EASE believes this is an underestimation, since more recent strong policy targets (such as REPOWEREU's 45% RES generation target, and the 55% GHG reduction target of the Fit for 55 package) are often not taken into account.[138] Especially higher RES growth and industrial decarbonization will further push the need for more energy storage capacity in the coming years.

Within these storage technologies, the following are the main storage technologies in the coming decades[139]:

- Pumped hydro storage remains by far the largest amount of storage on the grid (in terms of volume). This mature technology is expected to continue growing in the future, albeit at a rate slower than hydrogen storage and batteries.
- Hydrogen is expected to play a large role in balancing electricity supply and demand over long time intervals, and also allow for transportation of energy more easily.
- Batteries currently represent a tiny portion of storage needs in Spain and in the EU.[140] However, lithium-ion chemistries are the most rapidly growing storage technology and are expected to significantly change the storage landscape in the coming years.
- Molten salts are commonly used and developed as a storage solution, especially for renewable energy sources.
- Flywheels and similar mass-based storages are used extensively as spinning reserve for short-term frequency regulation.
- Similarly, supercapacitors will be used for very-short-term frequency response.

Most of the technologies listed here depend on mature supply chains and grow at less rapid paces. **We did not identify significant criticalities that are specific for these technologies, which include pumped hydro storage,[141] flywheels, supercapacitors, and molten salts.** The transversal barriers that impact all technologies, including these, are discussed further in Section 4.3.

Other technologies are too immature to reveal clear barriers, and thus needs for supports measures. Specifically, redox flow batteries are one such promising technology, especially given their separation of

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[138] EASE (2022), Energy Storage Targets 2030 and 2050.
[139] ibid.
[140] European Commission (2020), Study on energy storage – Contribution to the security of the electricity supply in Europe
[141] Trinomics (2021), Study on the resilience of critical supply chains for energy security and clean energy transition during and after the COVID-19 crisis

attributes impacting capacity (kW power transfer) and volume (kWh energy stored). The technology for these batteries is yet to reach high maturity, and thus does not present clear technological dependencies.[142]

The main technologies which present criticalities given predictions for their rapid growth are hydrogen and batteries. The following text first covers batteries along the entire value chain, while some content specific to the electric mobility use case is separated into Section 0 . Hydrogen storage and infrastructure is also discussed afterwards.

4.1 Batteries

Batteries use various chemical processes to store and release electrical energy based on need. These devices have become commonplace in various electronics, and rechargeable options are expanding across energy infrastructure, especially for end-uses in **mobility and grid storage**.

In **grid storage**, batteries are envisioned at both small and large scales. At small scale, batteries are usually paired with residential households installing solar PV panels. At a larger scale, utilities and other operators install batteries for grid flexibility and energy storage. Some other uses in commercial settings also exist, such as for backup power in critical use-cases. Expert interviews highlight that batteries are quickly taking over as the preferred storage solution among different options. Batteries are also used in electric mobility, which is discussed in Section 0.

In 2021, Europe's demand for EV batteries and grid-installed batteries amounted to 90 GWh and 5 GWh, respectively. This amount is growing rapidly, and annual demand is projected to grow to 250-300 GWh by 2025.[143] The continent currently represents a quarter of global demand for batteries, with this share decreasing in the coming decades. For Spain, battery demand is expected to follow European trends. For stationary storage, the government has set targets of 0.5 GW by 2025 and 2.5 GW by 2030 in the PNIEC.[144]

In the following sub-sections, we analyse the value chain for batteries and subsequently we provide a brief discussion of their main applications, namely **electric mobility and the energy storage sectors**. The batteries value chain is almost entirely (>90%) focused on producing EV batteries and it will remain so for the foreseeable future.[145] Thus, we place the main emphasis on these use-cases and give supplementary information about stationary battery installations.

In terms of chemistry, Lithium-ion based batteries have gained widespread usage in these applications. Nonetheless, it also worth mentioning growing use of Sodium-ion based battery chemistries, with a recently-announced end-use in e-mobility[146], and other potential chemistries, such as lithium metal and lithium air batteries. Due to the lower development of the technologies and the associated supply chains, it is unclear what amount of usage they will have in the future and how vulnerable their supply chains may be. Thus, in the following analysis we focus primarily on Lithium-ion based batteries.

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[142] It is for example likely that Vanadium, the main critical material used in this battery, can be reduced or removed by using a novel electrolyte chemistry containing less critical materials.

[143] KU Leuven (2022), Metals for Clean Energy: Pathways to solving Europe's raw materials challenge.

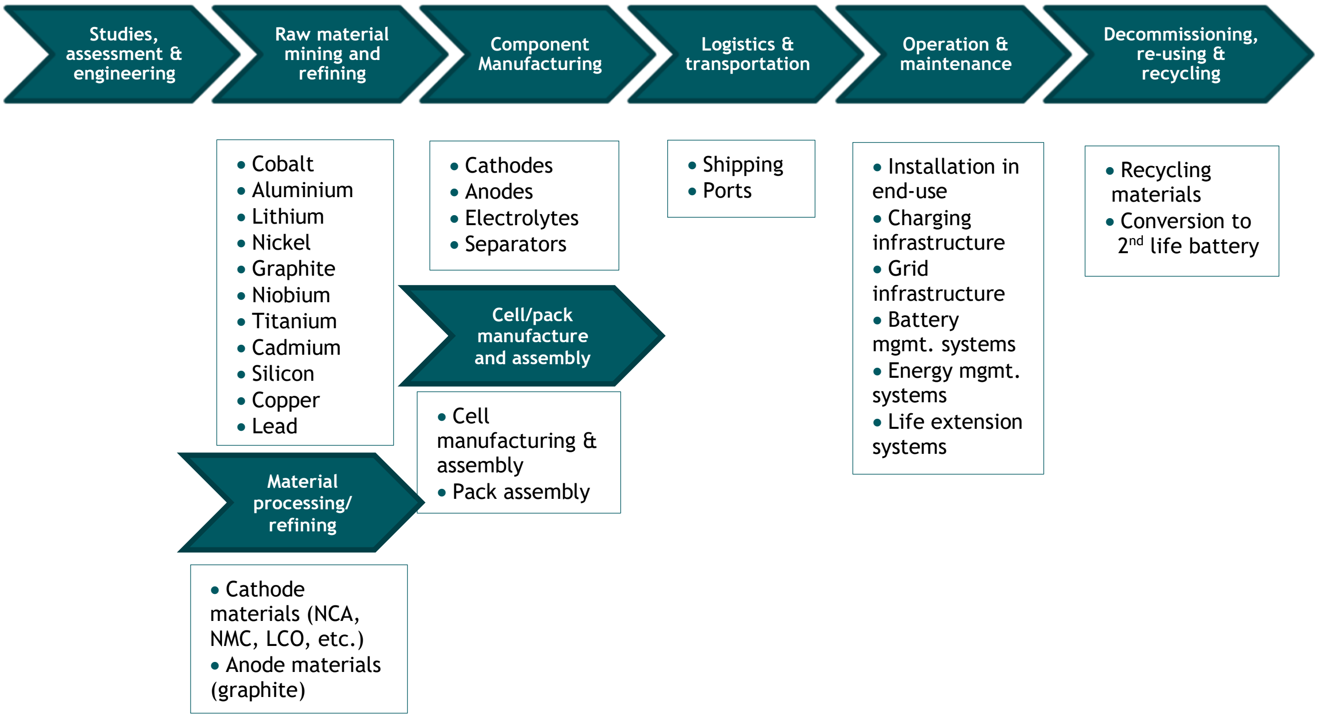
[144] MITECO (2020), Plan Nacional Integrado de Energía y Clima (PNIEC) 2021-2030

[145] KU Leuven (2022), Metals for Clean Energy: Pathways to solving Europe's raw materials challenge.

[146] https://www.notebookcheck.net/First-electric-car-with-cheap-sodium-ion-battery-offers-157-miles-of-range-as-it-appears-out-of-a-VW-partnership.697298.0.html

4.1.1 *The battery value chain at the European level*

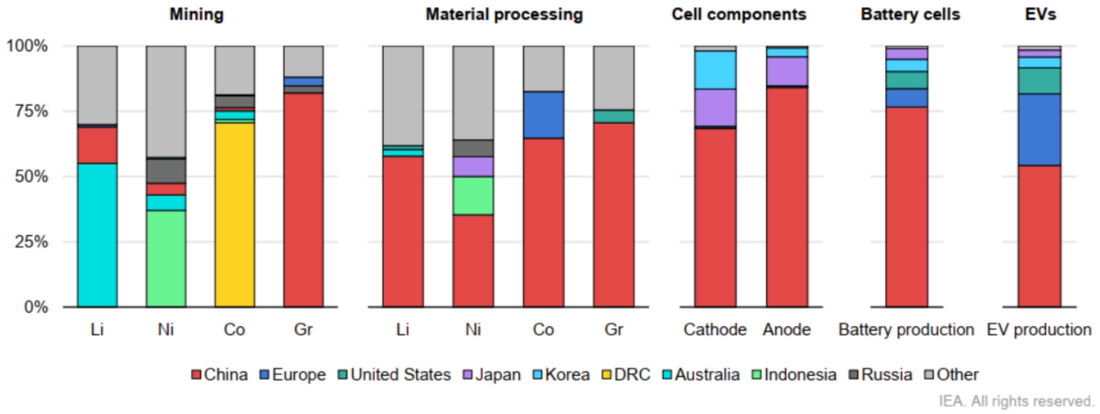
Figure 4-2: Lithium ion battery (LiB) value chain[147]



The main components of the batteries value chain and Europe's dependencies in this regard are:

1. **Raw materials mining and refinement:** Raw materials are especially critical in the battery value chain. The cost of materials constitutes about 50-70% of a battery's final cost,[148] and they are thus one of the most important segments in the value chain. A previous study on critical supply chains of energy technologies[149] identifies cobalt, aluminium, lithium, nickel, copper, cadmium, lead, and graphite as important raw materials in the battery value chain. In addition, other materials including silicon, titanium, and niobium are expected to be key materials in the future production of battery components.[150] For the critical materials, Europe relies on imports for most of the raw and processed material supply (See Figure 4-3).

Figure 4-3 - Geographical distribution of battery value chain and EV production. Source: IEA (2022)[151]



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[147] COM(2018) 293 final - ANNEX 2 Strategic Action Plan on Batteries .

[148] IEA (2021), The Role of Critical Minerals in Clean Energy Transitions.

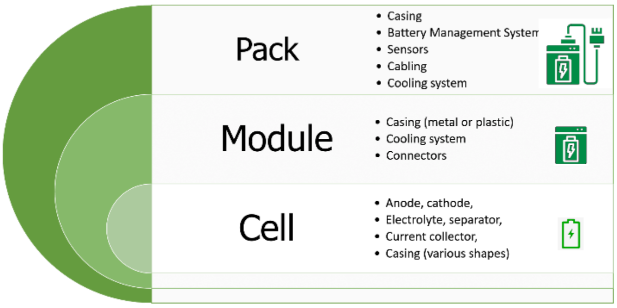
[149] Trinomics (2021), Study on the resilience of critical supply chains for energy security and clean energy transition during and after the COVID-19 crisis

[150] IEA (2020), The role of Critical Raw Materials in Clean Energy Transitions

[151] IEA (2022), Global Supply Chains of EV Batteries.

2. **Component manufacturing:** In the context of batteries, this refers to the production of materials for and of cathodes, anodes, electrolytes, and separators. The critical components here are cathodes and anodes, for which Europe is almost entirely dependent on East Asian producers. China, Japan, and Korea together produce over 97% of these components, and, absent policy intervention, Europe's heavy dependence is expected to continue in the coming decades.[165]
3. **Cell/Pack manufacturing and assembly:** Manufacturing consists of two steps: battery cell manufacturing followed by battery pack manufacturing. Battery cells form the fundamental unit for battery storage devices, and consist of a cathode, an anode, an electrolyte, and separators. Cells are then clustered together in modules to make packs. Pack components include electrical connectors, sensors, casings and a cooling system. Figure 4-4 shows the makeup of batteries.

Figure 4-4: Makeup of batteries[152]



This step of the battery value chain has been heavily concentrated in China, Korea, and Japan, especially for cell manufacturing which benefits from closeness to the manufacturing centers of its constituents (anode and cathode chemicals, especially). However, in more recent years, Europe and other regions have great expanded battery cell and pack manufacturing and assembly capacities. Many planned announcements and expansions of battery production in various regions are also expected to increase production in the coming years. the ambitions of the EU block are to meet 69% of domestic demand by 2025 and 89% of demand by 2030.[153] The top European battery plants are located in Hungary (Samsung SDI and SK Innovation), Poland (LG Chem), Sweden (Northvolt) and Germany (CATL).[154] Nonetheless, in Europe, this supply growth may not keep pace with demand growth, as many battery end-uses are expanded across the continent.

4. **Logistics and transportation:** This refers to activities involved in delivering batteries to the end-uses in the e-mobility and storage sectors. Europe is not foreseen to have bottlenecks in this regard. This segment of the supply chain can also appear in relation to the raw materials that could be transported for processing, and, possibly also refining, away from the mining places. The refining and processing can take place in the EU or in other locations outside the EU.
5. **Operation and maintenance:** In the context of batteries, this refers to their installation in the identified end-uses and their operation in that end-use. Relevant infrastructure includes charging infrastructure (for the mobility use-case) and grid infrastructure (for both mobility and storage use-cases).
6. **Decommissioning, re-using, and recycling:** Li-ion batteries contain many metals, which are chemicals that respond well to recycling. The EU is relatively well-positioned globally with established existing collection and recycling practices. The EU's circular economy action

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[152] https://rmis.jrc.ec.europa.eu/apps/bvc
[153] https://ec.europa.eu/commission/presscorner/detail/en/QANDA_22_1257
[154] https://www.automotive-iq.com/electrics-electronics/articles/top-five-ev-battery-factories-in-europe

plan (CEAP)[155], adopted in 2019, includes initiatives for, among others, the improvement of the markets for secondary raw materials (SRM)[156], including recovery of critical raw materials (CRMs) from batteries.

To advance towards strategic autonomy on batteries production, the European industry has come together by forming the European Battery Alliance (EBA), which was launched by the European Commission in 2017. The alliance is currently hosting more than 700 industrial and innovation members. Their goal through the EBA250 industrial project is to create a fully European value chain of batteries. The project includes actors along the whole chain, from innovators, academics and investors to producers, as well as mining and recycling companies. In addition to this, the EU Commission is set to invest about €200 million in battery research and Innovation.[157]

Overall, it is imperative that battery manufacturing is developed in Europe to reduce the dependency on the supply from the more advanced Asian producers. Manufacturers of end-uses for batteries have preferences to settle close to supply chains to minimize supply risks. Given the enormous economic and technical importance of batteries in the architecture of an EV, should Europe fail to attract battery manufacturers, the block may lose competitiveness altogether in the automotive industry. Such a scenario would have serious consequences for the job market and social consequence in general. If, on the other hand, Europe does follow through with creating battery production capacity, there is a potential of creating 250 thousand jobs in this industry, including within battery-cell manufacturing and R&D.[158] These could partially offset the loss of jobs in the ICEV industry due to the transition to EM.

Beyond ensuring the internal production of batteries, for competitiveness purposes, the EU must also develop the industry for recycling elements of batteries and generate technologies for their reuse and re-purposing at the end of life. Developing technologies and strategies for reusing, repurposing and/or recycling can also contribute to alleviating the risks of supply of raw materials that are often mined[159] in politically volatile regions and/or regions with serious breaches of human rights,[160] and with non-negligible environmental risks and social challenges. While recycling of batteries is still an energy-intensive process, a closed loop of battery manufacturing can still support sustainability, thus creating a significant competitive advantage for Europe. Moreover, the battery recycling industry can be another source of new jobs to compensate for the loss of jobs in the manufacturing sector of the classical internal combustion engine vehicles.

In Section 0 we discuss the potential challenges related to batteries in their largest use-case (EVs), as well as challenges regarding charging stations and other grid infrastructure needed for this technology.

4.1.2 *Mapping the battery value chain at the Spanish level*

Sourcing of raw materials mining and refinement

For batteries, the most critical material is lithium, as no good substitutes exist yet for this application. In fact, the metal is primarily used in the supply chain of batteries. Currently, most of the global market

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[155] https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en

[156] https://rmis.jrc.ec.europa.eu/?page=why-crms-have-a-supply-risk-8e8af9

[157] https://single-market-economy.ec.europa.eu/industry/strategy/industrial-alliances/european-battery-alliance_en

[158] McKinsey and Company (2019), Recharging economies: The EV-battery manufacturing outlook for Europe

[159] Among the mining places count: China, Indonesia, Democratic republic of Congo, Russia. See https://iea.blob.core.windows.net/assets/ad8fb04c-4f75-42fc-973a-6e54c8a4449a/GlobalElectricVehicleOutlook2022.pdf, page 154

[160] https://www.business-humanrights.org/en/latest-news/tracking-human-rights-violations-environmental-impacts-in-lithium-batteries-supply-chains-in-china-drc-so-america/

for lithium is supplied from Australian, Chinese, and Latin American sources. For Europe, the main suppliers of refined lithium are Chile (>50%), Argentina, and the US.[161] The EU-27 have announced multiple mining and refining efforts for lithium. However, supply will probably be far short of what is needed for the EU's own upstream battery production in the next few years. From 2030, recycled and locally-sourced lithium can become a large source of lithium for Europe.[161] However, this is contingent on the widespread development of lithium recycling from batteries and the commissioning of internal mining and refining projects. The former will be significantly pushed further by the proposal for the revision of the 2006 Battery Directive which foresees minimum material recovery rates for lithium of 35% by 2026 and 70% by 2030.[162]

Nickel, cobalt, and graphite are also critical materials for use in cathodes and anodes. While Europe has a significant refining capacity (70% of internal market demand[161]), this cannot be exploited due to a lack of resources for mining activities. Therefore, for nickel, much of Europe's supply arrives from Russian and Canadian sources, a dependency which will grow significantly in the near term.[161] Cobalt is also mostly used for batteries, similar to lithium, and is mostly mined in the Democratic Republic of Congo (DRC). In recent years, many concerns have been raised regarding the environmental and social conditions of mining in the DRC, many of which are targeted at copper (and cobalt as a by-product of copper and other mining operations).[163] To alleviate these concerns and for economic reasons, battery producers have migrated towards low-cobalt chemistries, which use other materials (such as aluminium and manganese) as a partial replacement for cobalt. Overall, the EU-27 bloc is unlikely to experience a shortage of refined cobalt in the long term.[164] Lastly, for graphite, China is home to about three quarters of mining and refining operations. Graphite can be made synthetically as well as refined.

Aluminium and manganese are also used in some battery chemistries, which replace some cobalt with aluminium and/or manganese. But the metals' primary use is outside of the battery sector, and neither is a critical element as they can be substituted.[161,165]

Because of economic factors (e.g. high prices for cobalt and nickel) and technological factors (e.g. better life cycle), some battery producers have moved towards lithium iron phosphate (LFP) chemistries. In addition to lithium, LFP chemistry contains less critical materials such as iron and phosphorus. LFP's higher life cycle rate, lower energy density, and suitable discharge properties make it especially appealing for stationary storage. Growing demand for LFP chemistry in shorter range EVs will help its adoption in stationary uses. LFP batteries have been almost entirely made in China, due to limitations set by the patent owners. These limitations expired in 2022, which has created a surge in interest within many markets (including the EU-27[166]) to greatly expand LFP production.[165]

Figure 4-5: Material composition share of different battery cathodes and Light-duty vehicle sales share per battery chemistry. Source: IEA (2022)[9]

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[161] KU Leuven (2022), Metals for Clean Energy: Pathways to solving Europe's raw materials challenge, available at https://eurometaux.eu/media/20ad5yza/2022-policymaker-summary-report-final.pdf.

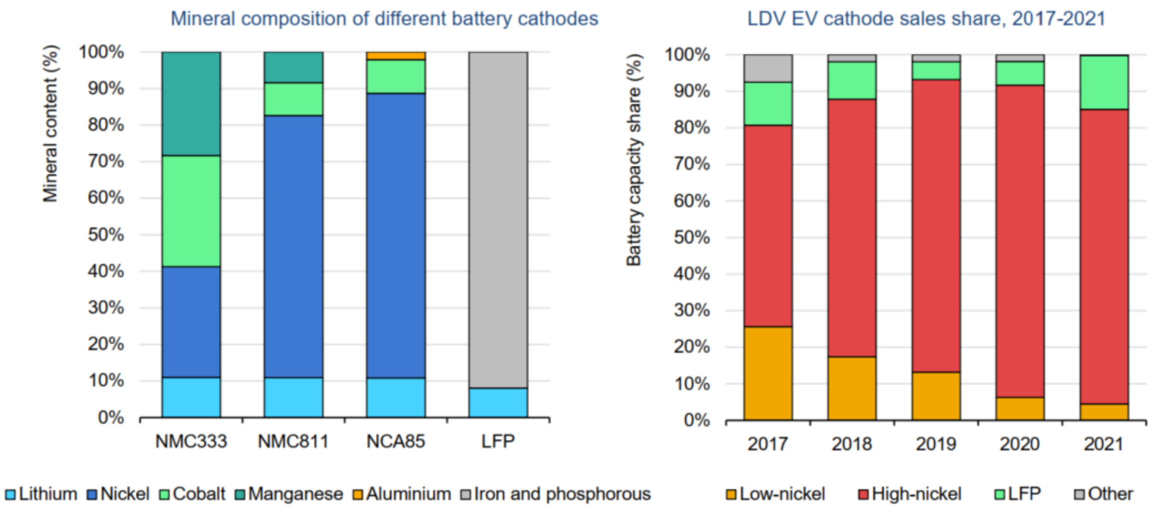
[162] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A52020PC0798 (Annex XII)

[163] This is also true for other metals belonging to the supply chain of batteries, and in particular for the lithium extracted from the mines of South America.

[164] IEA (2022), Global Supply Chains of EV Batteries.

[165] IEA (2022), Global Supply Chains of EV Batteries.

[166] https://www.electrive.com/2021/10/22/elevenes-to-build-lfp-batteries-in-europe/



IEA. All rights reserved.

Much of the supply for raw materials for the battery value chain come from outside the EU. Thus, most of the dependencies of Spain in this regard are similar to those at the EU level. Spain has however taken multiple actions to develop self-sufficiency and reduce dependencies in critical raw materials for the energy transition. The government has created several roadmaps for the development of self-sufficiency in raw materials in clean energy technologies, including batteries.[167,168] However, these ambitions are being met with much opposition on social and environmental grounds. For example, the potential development of lithium mining and refinement operations in Extremadura is facing difficulty due to local opposition to the project.

Manufacturing of components

Similar to raw materials, component manufacture, especially anode and cathodes, come from extra-EU sources. These dependencies for Spain are also similar to those at the EU level. Nonetheless, Spanish roadmaps for self-sufficiency in the energy transition also focus on developing component manufacturing, especially the necessary chemicals for battery cathodes and anodes, internally.[169,170] Currently, the manufacturing of anodes and cathodes, along with their constituent raw minerals, are seen by experts as the biggest risks in Spanish manufacturing of batteries.

Cell/Pack manufacturing and assembly

Similar to the aforementioned sections, the EU (including Spain) is highly dependent on foreign producers (especially Chinese producers) of battery cells and packs. The decarbonization policy in the EU and around the world has brought a momentum for the producers of EV batteries and their market is expected to reach close to 100 billion USD by 2028. Despite this momentum, the EU does not have a battery producer in the top 10 world producers and the world market is dominated by Asian companies (mainly China, South Korea and Japan), with the Chinese companies having a 56% market share in 2022. In fact, the Chinese company CATL is the world market leader with 34% market share in 2022.[171]

Spain has until recently made little progress in attracting investment for developing battery manufacturing plants. This is an urgent matter given that it is estimated that Spain will need at least 2-

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[167] MITECO (2020), Borrador de la estrategia de almacenamiento energético.
[168] MITECO (2022), Hoja de ruta para la gestión sostenible de las materias primas minerales.
[169] MITECO (2020), Borrador de la estrategia de almacenamiento energético.
[170] MITECO (2022), Hoja de ruta para la gestión sostenible de las materias primas minerales.
[171] https://www.visualcapitalist.com/the-top-10-ev-battery-manufacturers-in-2022/

3 factories in order to satisfy the EV battery demand in 2030. While the national and regional governments of Spain have started to catch up, the country still lags behind both regarding established battery manufacturing plants and advanced plans for building battery plants compared to other major European manufacturing countries.[172] A recent JRC study collected plans for new installations, or expansions of existing installations for battery cell manufacturing in the EU. According to this study, 5 out of the 41 installations will be located in Spain.[173]

Table 4-1 Planned EU battery cell manufacturing capacity in Spain. Source: JRC (2023).[174]

Installation	Development status	Targeted Capacity (GWh)	Operating Capacity
BasqueVolt, Vitoria-Gasteiz	Construction Planned	2 (2025) and 10 (2027)	-
Phi4tech, Badajoz	Construction Planned	2 (2024) and 10 (2030)	-
Volkswagen, Sagunto	Construction Planned	10 (2026) and 40 (2030)	-
Envision AESC, Navalmoral de la Mata	Announced	10 (2025) and 30 (2030)	-
Phi4tech pilot, Noblejas	Under Construction	0.3 (2022) and 2 (2023)	0.3

The industry stakeholders interviewed during this study identify 4 ongoing “gigafactories” projects, which receive support from the PERTE funds. However, some of these initiatives may turn out to be only battery cell producers or only assembly of battery packs or, in some cases, activities attaining repurposing and recycling of end-of-life batteries. For example, in the summer of 2022, the Chinese Envision Group has announced a joint project with the Spanish renewable power company Acciona Energia to build an EV battery plant in Extremadura region, where there are large reserves of lithium.[175] This would be the second EV battery plant after the one announced to be built in 2023 by the Volkswagen Group and SEAT S.A.[176] In October 2020, the Slovak battery producer InoBat also signed an agreement with the Spanish government on the intention to build an EV battery factory in the city of Valladolid.[177] Worth noting also is the Battchain project[178] that plans to incorporate the whole battery value chain with 100% European technology.

Battery manufacturers, like most businesses, prefer locations that offer political stability, institutional, financial and business support. Other reasons cited by manufacturers for opening shop in Spain include an excellent talent pool[179] and good access to renewable energy.[180,181]

Logistics (transport and distribution)

Due to the nature of battery manufacturing, infrastructure that facilitates the connection with and proximity to the downstream, e.g. auto-parts manufacturers and automotive producers, and to the upstream, i.e. the supply of raw materials, are also important. In this respect, Spain has a privileged

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[172] https://cicenergigune.com/en/blog/spain-europe-gigafactories-manufacture-electric-vehicle-batteries

[173] Carrara, S. et al. (2023). Supply chain analysis and material demand forecast in strategic technologies and sectors in the EU – A foresight study, EUR 31437 EN, Publications Office of the European Union.

[174] Ibid.

[175] Reuters (2022). China greentech company Envision to build EV battery plant in Spain.

[176] SEAT (2022). First battery Gigafactory in Spain.

[177] Reuters (2022). Slovakia's InoBat eyes electric car battery plant in Spain

[178] EIT Innoenergy (2021). Nace Battchain, el consorcio español de baterías para acelerar la recuperación económica verde

[179] Reuters (2022). Slovakia's InoBat eyes electric car battery plant in Spain

[180] Ibid.

[181] SEAT (2022). First battery Gigafactory in Spain.

geographic position with several well-connected ports for access to international raw-materials markets[182], but also with regions rich in reserves of lithium, such as Extremadura.

Operation and maintenance

Batteries are primarily used in electric mobility (especially EVs) and secondarily in stationary storage. With an annual turnover of €340 billion, and directly employing 1.2 million (and indirectly another 1.7 million via suppliers), the automotive industry is one of the most important industries of the EU bloc.[183] The transition to EM in this sector will have the potential to create many new jobs. However, many jobs will also be lost due to the obsoletion of many technologies and parts in internal combustion engine vehicles (ICEVs). A study by CLEPA (European Association of Automotive Suppliers) estimates that until 2040, the transition to electrification will lead to a loss of about 500 thousand jobs currently employed in ICEV production, namely a reduction of 84% relative to the employment in 2020.[184]

Thus, the current occupants of the jobs that will disappear as a result of the transfer to EM, can be retained, retrained and transferred to the jobs newly created in the EV domain. However, one of the biggest challenges of the transition to EM is the lack of appropriate skills for this industry. Moreso, the process of skills transfer from the ICEVs to EVs through re-skilling and up-skilling may be time-consuming. Therefore, a long-term vision and preparation are crucial for a successful transition. Nevertheless, even with a successful re-skilling and up-skilling process and jobs transfer, it is estimated that the net loss of total employment in the automotive supplier sector will be more than 40% by 2040.[185]

There is also the potential for creating regional inequalities with EM. It is also estimated[186] that EV production will be concentrated in Western Europe while the automotive employers in Central and Eastern Europe are still concentrated on the production for ICEVs. Thus, countries in the latter regions are especially vulnerable to jobs losses in the coming decades.

For Spain, this stage of the battery value chain is especially critical, as it involves the automotive sector. Therefore, connections to downstream users of batteries, especially the automotive sector, is particularly appealing for battery manufacturers. Spain is the second automotives producer in Europe and thus offers one of the most attractive markets for battery plant development. The operation and maintenance of batteries in these use-cases also depends on the supporting infrastructure, namely grid infrastructure and charging stations.

Decommissioning, reusing, and recycling

The recycling of battery materials has the potential to supply much of the materials need for battery production. The cathode and anode materials can be retrieved by smelting (pyrometallurgy) and/or by chemical leaching processes (hydrometallurgy). These processes are already used to some extent, especially in battery-producing countries such as China, to recover critical and expensive materials. However, they return only a small fraction of the initial material, and more infrastructure and know-how is needed for more direct recycling methods that could recover a higher amount of the materials for re-

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[182] https://www.reuters.com/business/autos-transportation/slovakias-inobat-intends-build-electric-vehicle-battery-factory-spain-2022-10-19/

[183] CLEPA (2021), Electric Vehicles Transition Impact Assessment 2020-2040: Study on Workforce of Automotive Suppliers, https://clepa.eu/wp-content/uploads/2021/12/Transition-Impact-Study-Summary-brochure-study-EV-Impact-Assessment.pdf

[184] ibid

[185] ibid

[186] ibid

use.[187] This was especially emphasized by experts during interviews, who stated that both RD&I and capacity building is needed to meet Spain's battery needs.

The need for support for different metals also differs. Some metals, such as nickel and aluminium, are already recycled due to their high value and/or ease of recycling. In alloy or pure form, these metals are regularly recycled with about 45-60% of primary supply being recycled. Others, such as cobalt, are expected to reach higher recycling rates due to their high value, despite having very low recycling rates now (~5%). However, others, such as lithium, are not currently recycled at any significant scale, and the difficulty of their recycling may present issues in the future.[188] These metals will need larger support for both innovation and capacity-building efforts, especially to reach the very high rates of recycling (70% for lithium, 90% for nickel and cobalt by 2035) needed for a sustainable energy transition.

In Spain, experts indicate that currently no formal businesses are active in the battery recycling industry at high levels. One of the most plausible explanations for this being the lack of end-of-life lithium-ion batteries available at present. An electric vehicle's Lithium-ion battery's estimated life is around 10 years, which means the batteries being discarded today are those that entered the market 8-10 years ago.[189] The low waste volumes available is not yet sufficient to ensure the cost-effectiveness of the battery recycling processes. Discarded Li-on batteries in Spain are currently sent to France, Belgium or Germany for their disposal treatment.[190]

Nevertheless, a few projects on battery recycling have been announced and are expected to begin development or operations in 2023. A battery recycling plant by Ponferada Novolitio is expected to begin construction in Cubillos del Sil (León) in the second half of 2023. With an investment of €14m, the plan is expected to process about 8000 tons of lithium ion batteries per year.[191] Another plant by Econili, a subsidiary of the Korean-Malaysian company CarbonX, is expected to begin development in 2023 in Alicante, reaching an annual capacity of 45000 tons.[192] Some initiatives have also been started to develop battery recycling capabilities in Spain, including a partnership between FCC Ámbito, Iberdrola, and Glencore.[193] Overall, far higher capacities are needed to provide the battery manufacturing industry with the needed secondary supply of raw materials.

Batteries from EVs can also be re-used in stationary applications. The batteries are removed, sorted, and cells are graded and sorted based on quality. As with recycling, the reuse industry also faces challenges in terms of cost competitiveness with new batteries.[194] Experts indicated that some initiatives are already underway in Spain for re-using EV batteries in stationary storage.

A battery recycling industry that is economically viable involves easy and safe dismantling. Hence, good and nuanced regulation of this activity from the policy side is required such that, on the one hand, the recycling industry is not discouraged and, on the other hand, the safety and environmental risks are

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[187] IEA (2022), Global Supply Chains of EV Batteries.

[188] KU Leuven (2022), Metals for Clean Energy: Pathways to solving Europe's raw materials challenge.

[189] Plataforma Technologica Española de eficiencia energetica (PTE-ee) INICIATIVA TECNOLÓGICA PRIORITARIA 01-2022. Reciclado de baterías de iones. Published on December, 2022.
de litio de vehículo eléctricos

[190] ibid.

[191] https://www.endesa.com/en/press/press-room/news/energy-efficiency/circular-economy/born-novolitio-first-company-recovery-recycling-lithium-batteries-electric-vehicles-iberian-peninsula

[192] https://batteriesnews.com/econili-battery-inc-battery-recycling-facility-annual-capacity-spain/

[193] https://www.review-energy.com/almacenamiento/impulso-al-reciclaje-de-baterias-en-espana-como-apuesta-por-la-economia-circular

[194] IEA (2022), Global Supply Chains of EV Batteries.

minimized. Decreasing safety and environmental risks involves anticipating the recycling step at the design stage of the batteries when they can be built for easy and safe dismantling. For this, R&D investments are needed in order to provide the appropriate design while continuing to innovate for reducing costs and increasing performance. R&D investments are also required for the development of repurposing solutions (e.g. as stationary storage for EV batteries) because this type of investment is not immediately profitable. Additional solutions for re-using the batteries involve smart repairs in which the under-performing battery cells are replaced one-by-one, thus making use of the remaining battery pack and the still-good cells. However, policy support is needed at every step.[195]

4.2 Hydrogen storage and transport

4.2.1 At the EU level

Nowadays, in Europe hydrogen is produced close to where it is consumed. Consumers usually have limited options in procuring hydrogen, and the material is not traded globally at a significant scale (despite an established global trade in ammonia).

With the rapid expansion of renewable energy, and hydrogen's promise as an alternative clean energy vector, (renewable) hydrogen could potentially become a significantly traded commodity globally. Hydrogen can be a means of transporting energy from regions with abundant renewable resources to regions with high energy use and scarce renewables. Moreover, following demand and supply growth, more large-scale hydrogen storage will become necessary in both high-demand and high-supply regions.

Transport

Pipelines are usually the most efficient manner of transporting hydrogen, up to a few thousand km of over-ground distance. Hydrogen is a less dense gas than methane, so larger pipes and pressures are needed to carry the same amount of energy with the new energy vector. In some cases, transporting hydrogen via gas containers in liquefied or compressed form (as a single gas or together with other gases) may be an option. Lastly, longer distances may require the use of marine transportation options, similar to large LNG carriers. These options (containers and marine transport) however face other challenges, especially due to hydrogen's low boiling point and density making such transportation having a higher boil-off and leading to greater liquefaction losses, thus lowering efficiency. Transforming hydrogen within other chemical compounds, for example as ammonia or via liquid organic hydrogen carriers (LOHCs), circumvents these issues. However, these transformations to and from the carrier cost more energy and reduce overall efficiency, and related projects are still undergoing technical and economic feasibility studies.

In Europe, prior to the REPowerEU's announced targets (10Mt/y production plus 10Mt/y import of hydrogen), modelling studies developed predictions of hydrogen transportation infrastructure development. Prominently, the European Hydrogen Backbone (group of 31 energy infrastructure operators) foresees 5 hydrogen corridors in Europe by 2030. These include (Figure 6-1):

a) North Africa and Southern Europe
b) North Africa and the Iberian peninsula
c) North Sea
d) Nordics and Baltics
e) East and Southeast Europe

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[195] KU Leuven (2022), Metals for Clean Energy: Pathways to solving Europe's raw materials challenge.

Figure 4-6 - 5 hydrogen corridors from EHB study. Source: OGE (2022).[196]

The EHB plan contains 53 000 km of pipelines, with 60% repurposed natural gas infrastructure and 40% purpose-built new pipelines, costing overall €80-143 billion. The plan assumed no import of hydrogen through marine transport, and predicted 12 Mt/y of intra-EU supply and 5.4 Mt/y of imports.

Europe has limited experience with repurposing natural gas pipelines for transporting hydrogen. The primary experience is a 12 km pipeline supplying a chemical manufacturer in the South of the Netherlands.[197] Nonetheless, many European projects for transporting hydrogen involve the repurposing of existing natural gas infrastructure. Many thousands of kms of natural gas pipelines are already under assessment for conversion for hydrogen transport, including in projects in Germany (Hyperlink[198], H_2ercules[199]), Netherlands (Hydrogen Network Netherlands[200]), Italy (Snam 2030 Vision[201]), and international projects (Green Octopus[202], Danish-German Hydrogen Network[203]). Overall, the large-scale decarbonization of industry and other hard-to-abate sectors in Europe is planned on the basis of a functional and high-throughput hydrogen infrastructure.

Storage

Hydrogen storage will also be necessary to correct for fluctuations in supply and demand of hydrogen. Similar to natural gas, this storage will mostly consist of underground geological formations, especially

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[196] OGE (2022). Press release: EHB publishes five potential hydrogen supply corridors to meet Europe's accelerated 2030 hydrogen goals.

[197] https://www.gasunie.nl/en/news/gasunie-hydrogen-pipeline-from-dow-to-yara-brought-into-operation

[198] https://www.gasunie.de/en/the-company/gasunie-deutschland/project-hyperlink

[199] https://www.rwe.com/en/press/rwe-ag/2022-03-24-oge-and-rwe-present-national-infrastructure-concept--h2ercules/

[200] https://www.gasunie.nl/en/projects/hydrogen-network-netherlands

[201] https://www.snam.it/export/sites/snam-rp/repository/file/investor_relations/presentazioni/2021/2021_2025_Strategic_Plan.pdf

[202] https://www.waterstofnet.eu/_asset/_public/greenocotpus/GreenOctopus_Factsheet.pdf

[203] https://en.energinet.dk/Gas/Gas-news/2021/04/27/GUD-rapport/

salt caverns and when technological issues have been addressed depleted natural gas fields. Smaller amounts of hydrogen can also be stored in liquid or gas form within tanks, or as the energy carriers listed above in silos and ports/storage hubs. Although hydrogen demand is predicted to be less fluctuating than natural gas, Europe will still require large stores of hydrogen for its clean energy future due to high supply intermittency of green hydrogen.[204] Across Europe, many salt caverns and depleted natural gas fields are being repurposed as hundreds of GWh of hydrogen storage, including in Netherlands, Germany, France, Ireland, and Denmark.[205]

4.2.2 Mapping hydrogen storage and transport at the Spanish level

One of the primary factors in Spain's future in the hydrogen industry is being able to export hydrogen to other EU countries. Within the European Hydrogen Backbone study, this is envisioned through Corridor B, which is a pipeline transporting hydrogen from the Iberian Peninsula through France into Germany and other countries. In total, the pipeline will cover 10 000km by 2030 and connect 6 Mt per year of demand primarily in France, Germany, and Spain (1.4 Mt/y). The predictions of the EHB study are rather ambitious on hydrogen supply and demand, and forecast further growth of Spanish demand to 7.8 Mt/y by 2050. On the supply side, the EHB study predicts Spanish supply of 2.2 Mt/y of (mostly green) hydrogen in 2030.

The original Corridor B pipeline which connected Spain to France, titled "Midcat", has now been replaced by the "BarMar" pipeline. The BarMar pipeline instead takes an undersea route to transport hydrogen between Barcelona, Spain, and Marseille, France. BarMar is part of the H2Med pipeline project, which intends to bring green hydrogen produced on the Iberian peninsula to heavy industry in France and Germany. The green hydrogen will be used as both a chemical feedstock, replacing grey hydrogen, and as an energy vector, replacing mainly natural gas. In addition to this plan, the EHB also foresees imports of hydrogen from Morocco via repurposing the existing natural gas pipeline, Maghreb-Europe.

The high potential for supply and demand of hydrogen via the BarMar pipeline emphasizes the importance of fast-tracking and supporting hydrogen transport and storage infrastructure in Spain. Policy support needs to ease the transition for both suppliers and consumers of hydrogen by supporting the initial infrastructure needed for hydrogen trade. In addition to providing financial instruments for de-risking investments into transport and storage infrastructure, faster and coordinated permitting processes are needed to speed up pipeline development to match development of hydrogen supply and demand. Regulators must also place emphasis on tighter coordination between Member States to ensure integrated grid planning and that multi-national projects progress rapidly (especially the BarMar pipeline).

4.3 Enabling factors of energy storage value chains

There were a number of barriers related to regulatory aspects that are relevant for most of the energy storage technologies, alongside the ones discussed earlier, that were highlighted during the expert interviews. These are:

- **Complex permitting process:** The permits to be obtained for testing energy storage solutions are the same as those required for productive investments, which in the energy sector have a long lifetime, while those for testing are operational for only 1-2 years. Permitting requirements could become simpler for testing projects to better develop the opportunity for regular facilities.

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[204] IEA (2023), Energy Technology Perspectives 2023

[205] IEA (2022), Global Hydrogen Review 2022.

- With the **current regulatory scheme**, where energy storage plants are only charged if they receive surplus energy to accumulate, it is not cost-effective to do projects that have capacity for medium or large volumes. In this framework, this is perceived as a barrier blocking the possibility of energy storage deployment. Stakeholders propose the implementation of capacity mechanisms as critical for boosting investments in storage which, complemented by other supporting policy measures, would create the necessary conditions for the value chain to develop.
- **Lack of policy continuity** in Spain is perceived as a long-term issue for energy storage. Interviewees remarked that there is no national strategy sustained over time (when governments change, policies change), to bolster the strong links in the chain and support the weak ones.
- **Some energy storage technologies face financial difficulties for commercial scale-up** since they are still at an intermediate technology readiness level (TRL). These include the development of molten salts and liquid air, as well as certain stages of the value chain, such as battery recycling processes. The latter currently does not have the necessary scale in terms of volume to be considered profitable, but which in a few years will be a key link in the chain, providing sustainability and competitiveness to the sector.
- **Complexity of financial aid programmes:** While there are financial aid programmes in Spain, the high bureaucratic burden faced by applicants significantly limits their effectiveness. Reducing the bureaucratic burden is proposed, by reducing the procedures for obtaining aid as well as extending the deadlines. Along the same lines, it is suggested that the "Anglo-Saxon Model" be set up, which, unlike the "Mediterranean Model", which establishes restrictive ex-ante mechanisms to avoid fraud, imposes far fewer entry restrictions, but is much more rigorous and severe in the ex-post control of the use of these resources.

4.4 Barriers in Spain for the energy storage value chain

The multiple barriers identified in the prior text are summarized in Table 4-2. Desk research was complemented by six interviews, where the perspective of two associations[206] and three companies[207] were collected.

Overall, the main barriers for batteries relate to raw materials, anode and cathode production, charging and grid infrastructure, and re-using and recycling. Other barriers relate to hydrogen storage and to multiple storage technologies. Some barriers and measures also relate to renewable energies (especially solar and wind power) and electric mobility.

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[206] In the case of one of them, two interviews were carried out, one with a more institutional perspective, and the other with a technological perspective, which in turn provided the perspective of the research sector.

[207] Two companies are dedicated exclusively to the storage chain, and the remaining one manufactures components that are also used in the solar PV and hydrogen value chain.

Table 4-2 Summary of key barriers and needs identified per value chain segment

Value Chain segment affected	Barriers and needs identified	Associated measures to accompany and boost the value chain
Batteries: Raw materials mining and refinement	• High risks of supply for critical minerals such as lithium and cobalt • Slow development of local CRM resources • Dependencies on foreign technologies and know-how for CRM refining such the case for Chinese companies and Lithium	• Support measures for mining operations of CRM such lithium in Extremadura should be put in place to accelerate project deployment and create an integrated downstream value chain • Support the exploration and feasibility studies of CRM resources such as Cobalt in mineral deposits in Huelva • Increasing the R&D funding to develop local refining technologies • Boost circular economy through eco-design and recycling technologies to reduce mined mineral need • Create partnerships and integrate with cell manufacturers that have better access to the critical raw materials
Batteries: Component manufacturing	• High supply risks for battery anodes and cathodes	• Support anode and cathode manufacturing industry (and industries of chemical precursors) integrating it with cell assembly to enlarge local value chains and reduce dependencies on Asian suppliers • Invest in RD&I efforts into anode and cathode materials and manufacturing • Extending incentives for cell manufacturing to upstream component manufacturing • Requirement for Chinese manufacturers to have validated international certificates and meet standards
Batteries: Cell/Pack manufacturing and assembly	• Spain still lags behind other EU states in building EV batteries production plants • Lack of skills and know how (professionals and engineers) • Most demand for Spanish storage firms comes is foreign due to the lack of profitable use cases in Spain	• Financial support and de-risking to attract investments (e.g. fiscal relief, reduce the red-tape of permits etc.) • Facilitate alliances and consortia in the industry • Regulation to suitably monetise the advantages of stationary energy storage.
Batteries: Decommissioning, re-using and recycling	• Low expertise in recycling multiple critical metals and chemicals • Lack of standardization with decommissioning and re-use	• Invest in RD&I efforts into recycling technologies for metals, especially lithium and cobalt • Develop national standards for decommissioning and re-use of batteries
Hydrogen storage	• Slow development of transport, especially the BarMar pipeline	• Coordinating infrastructure efforts across Member States • De-risking investments in supply and demand via tailor-made financial instruments • Fast-tracking permitting for the pipeline and for relevant supply and demand projects
Transversal	• Complexity of financial aid programmes • Difficulty in financing scale-up for some storage technologies	• Simplify and streamline financial support options • Develop targeted financial support options for specific storage technologies to boost TRL

4.5 Mapping of existing initiatives related to energy storage.

Within the framework of the MRR, Spain has developed different energy storage initiatives related to some of the barriers listed above, under the umbrella of the Ministry for the Ecological Transition and the Demographic Challenge:

- **PERTE ERHA**[208]: *"PERTE de energías renovables, hidrógeno renovable y almacenamiento"*. As stated before is a strategic project dedicated underpin the areas associated with the energy transition in which Spain is well positioned and to strengthen those with less relevance. Its transforming measures are designed to meet challenges within three phases: R&D, Capacity Strengthening and Deployment. As part of this PERTE, there are three examples of grant public aid programs linked with some of the energy storage challenges:
    - **R&D for energy storage**: *"Proyectos innovadores de I+D de almacenamiento energético"* [209]. The purpose of this program is to grant public aid for R&D projects related to the deployment of energy storage. Projects funded under this call are expected to support pre-commercial development and demonstrations activities TRLs 6-8, advancing to TRL 9 after completion. Included on the measure 8 of PERTE on the R&D Phase.
    - **Hybrid energy storage**: *"Proyectos innovadores de almacenamiento energético hibridado con instalaciones de generación de energía eléctrica a partir de fuentes de energía renovables"* [210]. This funding scheme aims to support hybrid energy storage projects with renewable energy sources. This program is included in the transforming measure 10 of PERTE ERHA dedicated to the deployment of the energy storage system, deployment phase. Any technology allowing energy storage that can be incorporated into the electric grid is eligible for funding.
    - **Renewable hydrogen (including storage):** *"Programa H2 PIONEROS"* [211]. This program supports pioneering renewable hydrogen projects in the frame of measure 16 of PERTE on the deployment phase. Even though this call covers a wide range of initiatives related to hydrogen, incentivized actions can be related to storage (infrastructure for storage, conditioning and dispensing of renewable hydrogen, facilities and equipment for compression, transport and storage, etc).
  - **Mobility (including storage and batteries):** "Programa MOVES Proyectos Singulares II" [212]. MOVES Singulares II program offers grants for singular projects in the field of mobility. Eligible projects must prove a significant degree of innovation covering actions such as integration of renewable energies and storage in electric vehicle charging, the use of next generation batteries or giving batteries a second life. MOVES Singulares II is regarded as one of the enabling measures detailed in the PERTE VEC.

Energy transition in islands (including storage): "Transición energética en las islas" [213]. The goal of this program is to enhance energy transition in the islands through different actions. One the areas defined covers projects related to sustainable storage with renewable energy generation power.

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[208] PERTA ERHA.
[209] Proyectos innovadores de I+D de almacenamiento energético.
[210] Proyectos innovadores de almacenamiento energético hibridado.
[211] Programa H2 PIONEROS.
[212] Programa MOVES Singulares II.
[213] Transición energética en las islas.

5 Electric mobility

As part of the Fit-for-55 package, the EU Parliament has recently reached a provisional agreement to ban the sale of new cars and vans powered by fossil fuel in all 27 EU Member States by 2035.[214] This calls for a great transformation of the mobility industry and a significantly increased reliance on electric propulsion.

While all electric vehicles (EV) are propelled by electricity-powered engines, they differ in the way the necessary electricity is supplied to the motor. Thus, we distinguish four main types of EVs:

i. **Battery Electric Vehicles (BEVs),** which have engines powered by one or more rechargeable batteries and thus run solely on electricity;

ii. **Plug-in Hybrid Electric Vehicles (PHEVs)** are also propelled by re-chargeable batteries, but, in addition, they incorporate a small internal combustion engine that can recharge the battery or even directly power the wheels;

iii. **Hybrid Electric Vehicles (HEVs)** are similar to PHEVs, with the difference that the battery pack cannot be recharged; and

iv. **Fuel Cell Electric Vehicles (FCEVs)** use hydrogen that is converted into electricity that powers the motor.[215] The analysis below will focus on the first two categories that involved re-chargeable batteries, i.e. BEVs and PHEVs.

As mentioned in section 4.1, EVs, EV charging and grid infrastructure are important factors in the batteries value chain. McKinsey and Company[216] estimates 375,000 charging points in Europe in 2021, while the block requires 3.4 million public charging points by 2030.[217] In terms of values, the market for EV charging stations is expected to increase by 26.4% between 2021 and 2028, reaching 103.6 billion USD.[218] Unlike the market for EV batteries which is dominated by Asian companies, most of the top 10 companies in the market for charging stations have geographic presence and even originate in Europe (a number of them from the historical European utilities), including Schneider Electric SE, Siemens, ABB, Webasto or EVBox B.V.[219] This naturally offers a better position for Europe to move ahead with EM on this segment of the value chain.

Grid reinforcements are necessary to ensure the operation of charging infrastructure and integrate stationary batteries into the grid. The grid also requires communications and control infrastructure for smart charging, whereby the EV is able to put electricity on the grid and contribute to load management. Fast-charging stations are also needed on motorways to serve long-distance travel. Moreover, the charging stations will need to be inter-operable, to communicate among themselves and be connected to aggregators that combine capacity among multiple EVs in order to optimise load-balancing and make vehicle-to-grid operations possible. This will require coordination between the operators of the charging stations and the electricity providers. Finally, the charging stations will need to be connected to a

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[214] Press release of 28 October 2022: “Zero emission vehicles: first ‘Fit for 55' deal will end the sale of new CO2 emitting cars in Europe by 2035,” https://ec.europa.eu/commission/presscorner/detail/en/ip_22_6462

[215] https://www.transportation.gov/rural/ev/toolkit/ev-basics/vehicle-types

[216] https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/europes-ev-opportunity-and-the-charging-infrastructure-needed-to-meet-it

[217] The report does not distinguish between home and publicly available charging stations.

[218] https://meticulousblog.org/top-10-companies-in-electric-vehicle-charging-stations-market/

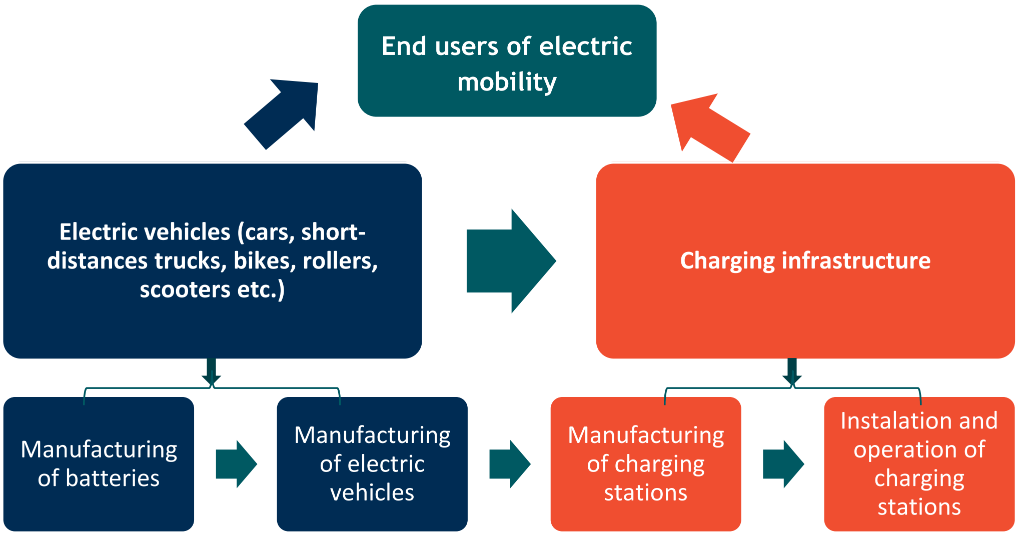
[219] https://meticulousblog.org/top-10-companies-in-electric-vehicle-charging-stations-market/, https://www.beny.com/best-5-ev-charging-station-manufacturers-in-europe/

harmonized payment system. This is something that does not yet exist at large scale[220] and requires both investment and labour, sometimes with specific skills, for building and maintaining this infrastructure. Importantly, unprecedented enabling legal framework will need to be developed to allow for the operations described above.

5.1 Electric mobility value chain in the EU and Spain

This section discusses the value chain for electric mobility, focusing on the manufacturing segment of EVs and on the charging infrastructure. A detailed description and discussion on the value chain for batteries, including components, cell and pack manufacturing, as well as logistics, decommissioning, reusing and recycling, can be found in Section 4.1. Figure 5-1 presents a simplified value chain for electric mobility.

Figure 5-1: Simplified value chain for electric mobility



Source: own figure

5.1.1 Manufacturing of batteries for electric vehicles

In the **mobility sector**, batteries are used for energy in passenger vehicles, large road vehicles (e.g. buses, trucks), and two- and three-wheel small vehicles, such as scooters and bicycles. Minor usage is also expected in specific use-cases in maritime and aviation transportation.

Batteries are the most important part of EM, as they are responsible for the actual propulsion of the vehicle. Moreover, they make up 35-40% of the total cost of an EV.[221] They are also bound to play a key role in the future in light mobility such as bicycles and electric scooters and heavy mobility such as trains, trucks and even airplanes and ships. While electrification provides emissions-free transportation at the tailpipe, have a low-to-zero GHG emission potential over their lifecycle and offer an alternative to oil (on which over 90% of the transport sector is dependent), batteries open a new host of challenges from the need for raw materials (nickel, lithium, cobalt etc.) to technologies for their repurposing and recycling at their end of life. More about battery manufacturing and batteries value chain can be found in Section 4.1.

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[220] https://www.eca.europa.eu/en/Pages/DocItem.aspx?did=58260

[221] McKinsey and Company (2019), Recharging economies: The EV-battery manufacturing outlook for Europe

5.1.2 Manufacturing of electric vehicles

The automotive manufacturing industry in the EU is one of the most important industries of the block, with an annual turnover of 340 billion Euro. The automotive suppliers in the EU are currently directly employing about 1.7 million people, in addition to the 1.2 million that are employed by the vehicle manufacturers.[222]

At the same time, Spain considers its automotive industry to be a strategic sector, being the second largest vehicle manufacturer in Europe and thus an important employer. Spain is becoming an important producer of electric vehicles, with at least seven vehicle brands produced in the electric or hybrid version.[223] The automotive manufacturing industry in Spain is currently employing about 230 thousand people.[224] In fact, its industry as a whole, including both vehicles and auto-parts producers, represents more than 10% of the manufacturing employment.[225]

Some of the parts produced currently for the internal combustion vehicles will become obsolete in the architecture of the EV and, therefore, discontinued. This will lead to job losses in the internal combustion engine sector and will require a transition of workforce to other sectors. A study by the European Association of Automotive Suppliers[226] estimates that until 2040, the transition to electrification will lead to a loss of about 500 thousand jobs currently employed in the production of vehicles with internal combustion engine. This means a reduction of 84% relative to the employment in 2020. However, the transition to EM will also create jobs, albeit for a different set of skills. While this shift of the types of jobs within the automotives industry is relatively undisputed, the estimates of the number of lost versus new (compensating) jobs vary widely.[227] Job gains will mainly occur from running and maintaining the infrastructure necessary for EM, ranging from the maintenance of the charging stations and charging networks to the build and maintenance of bike lanes. Indeed, a study by The European Association of Electrical Contractors (Europe-On)[228] estimates that around 57% of the almost 200,000 newly gained jobs in the electric passenger cars sector by 2030 in the EU28 countries are associated with the installation, maintenance and operation of the charging stations.[229] The study also estimates that the number of jobs created in the electricity value chain of the auto industry will be double the number of those lost in the automotive manufacturing, thus creating a net positive balance of new jobs. However, it is expected that the jobs lost will not be transferred one-to-one to the newly created jobs. It is, therefore, expected that the transition will still create unemployment, especially in the right tale of the age distribution for which re-skilling might be too costly.

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[222] CLEPA (2021) Electric Vehicles Transition Impact Assessment 2020-2040: Study on Workforce of Automotive Suppliers

[223] These are: Citroen, Peugeot, Ford Mondeo, Opel, Iveco, Mercedes and Nissan (https://anfac.com/wp-content/uploads/2019/07/ANFAC-Annual-Report-2018.pdf)

[224] CLEPA (2021), Electric Vehicles Transition Impact Assessment 2020-2040: Study on Workforce of Automotive Suppliers

[225] https://www.sernauto.es/en/el-sector, accessed November 2022

[226] CLEPA (2021) Electric Vehicles Transition Impact Assessment 2020-2040: Study on Workforce of Automotive Suppliers

[227] https://www.cleanenergywire.org/factsheets/how-many-car-industry-jobs-are-risk-shift-electric-vehicles. Moreover, the CLEPA (2021) study claims that by 2040, the net loss of total employment in the automotive supplier sector (upstream) will be of 40%. However, this could be compensated by the new jobs in the downstream segments as shown by the Europe-On study.

[228] Pek et al. (2020), "Powering a new value chain in the automotive sector: The job potential of transport electrification", Europe-On, accessed April 2023.

[229] The study assumes an EV market share of 35% by 2030, which translates into 10% EVs in the total passenger car fleet.

Nevertheless, most of the current occupants of the jobs that will disappear as a result of the transfer to EM, can be retained, retrained and transferred to the jobs newly created in the EV domain. However, one of the biggest challenges of the transition to EM is the **lack of appropriate skills** for this industry and that the process of skills transfer from the combustion engine vehicles to the EV through re-skilling and up-skilling may be tedious and long lasting. Therefore, a long-term vision and preparation are crucial for a successful transition.

Moreover, given the specificity of the raw materials for EV batteries and the preference of the vehicle producers to set-up plants closer to their supply chains in order to minimize the risk of supply shortage, the transition to EM risks to significantly disrupt the existing car manufacturing industry in Spain, should this not ensure supply chains close to home. Thus, in the first instance, the shift to electric mobility will imply **job displacement**. Given the already high unemployment rates and low wages in Spain, especially among the young,[230] this could create an additional pressure on the country's labour force.

5.1.3 Manufacturing of charging stations

The availability and affordability of charging infrastructure is crucial for alleviating distance anxiety for drivers and the competition for publicly available chargers in the cities to eventually encourage the adoption of EM. A report by McKinsey[231] estimates that there are currently 375 thousand charging stations of EVs in Europe[232] and that by 2030, the EM in the EU-27 would need at least 3.4 million public charging stations. In terms of values, the market for EV charging stations is expected to increase by 26.4% between 2021 and 2028, reaching 103.6 billion USD.[233] It is estimated that and investment of about 130 billion Euro will be needed for planning, engineering and installing new public and private charging stations.[234]

Unlike the market for EV batteries which is dominated by Asian companies, most of the top 10 companies in the market for charging stations have geographic presence and even originate in Europe, including Schneider Electric SE, Siemens, ABB, Webasto or EVBox B.V..[235] This offers a better position for Europe to move ahead with EM on this segment of the value chain.

The manufacturing of EV charging stations is also well represented in Spain. For instance, the Spanish start-up Wallbox, founded in 2015,[236] has started its production on four production lines in Barcelona in December 2021. The factory is currently producing 1,200 charging stations per day on a plant employing 203 people in the Zona Franca industrial estate. The factory is planning to increase its capacity by producing 750,000 chargers per year.237 The company is becoming global with offices in 9 countries and customers in over 80 countries worldwide. Next, the Portuguese manufacturer EFACEC also has presence in Spain under the name Efacec Equipos Eléctricos, S.L.U. Other EV charging stations manufacturers present in Spain are Endesa X in Madrid, specialized in wall-mounted home stations,

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[230] The unemployment rate among the 15-29 years of age was 27% in 2021 compared to the EU average of 13% and an overall unemployment rate of 14.8% compared to the EU average of 7% [Eurostat: LFSA_URGAN].

[231] https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/europes-ev-opportunity-and-the-charging-infrastructure-needed-to-meet-it

[232] The report does not distinguish between home and publicly available charging stations.

[233] https://meticulousblog.org/top-10-companies-in-electric-vehicle-charging-stations-market/

[234] https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/europes-ev-opportunity-and-the-charging-infrastructure-needed-to-meet-it

[235] https://meticulousblog.org/top-10-companies-in-electric-vehicle-charging-stations-market/, https://www.beny.com/best-5-ev-charging-station-manufacturers-in-europe/

[236] https://wallbox.com/en_ch/about-us/we-are-wallbox

[237] https://www.electrive.com/2022/04/21/wallbox-chargers-opens-factory-in-barcelona/

Ingeteam in Zamudio, producing wall-mounted home and outdoor charging stations, or Circontrol in Barcelona, manufacturing universal fast chargers.[238]

5.1.4 Installation, operation and maintenance of charging stations

A study published by the International Council of Clean Transportation[239] estimates that in 2019 Spain had between 10% to 12% of the necessary charging infrastructure for passenger cars that will be needed in 2025 and only 3% to 4% of the one needed by 2030. This is a huge gap that needs to be closed in a short period of time. Moreover, there is an imbalance between the North and the South regarding charging infrastructure, with the South lagging behind the North, with very few charging stations. Despite these gaps and imbalances, according to the Integrated National Energy and Climate Plan 2021-2030, the country aims at 500,000 charging stations by 2030, for a fleet of 5 million EVs, including passenger cars, vans, buses and motorcycles.

Regarding charging stations availability, Spain came just behind Greece and Switzerland and above the EU average, being very close to reaching the 2020 target of 10 EVs per charging station foreseen by the Alternative Fuel Infrastructure Directive. However, this ratio has worsened in 2021 reaching 20 EVs per charging point,[240] showing that the EV fleet has increased faster than the charging infrastructure. [241] This may reflect a dynamic EV market and a reassurance for the investors in the charging infrastructure that they have a reason to catch up. With several local EV charging stations manufacturers and several key players active in installing charging stations (e.g. Iberdrola, Repsol)[242] across the country, Spain has the full potential to close this gap and reduce the number of EVs per publicly accessible charging station.

For EVs to be able to respond to all types of drivers' needs, they will need to become available for long-distance travels. This implies the need for fast-charging stations, with power greater than 22kW installed on highways. In 2021 there were only 2,600 publicly available fast-charging stations in Spain, the same as in the Netherlands, a country 12 times smaller and more than 3 times less than in Germany, a country with an area slightly smaller than that of Spain. However, it is promising that Spain is moving to develop megacharging infrastructure for electric heavy-duty freight trucks through its multinational electric utility Iberdrola, who is planning to install a megacharger infrastructure by 2025.[243]

For the operation of the charging infrastructure at the capacity required as of 2030 by the EU-27 countries, the distribution grid will need to be reinforced and upgraded. The purpose is twofold. First, the distribution grid must extent to reach the new charging stations. Second, it needs to be able to avoid over-load and to allow for smart charging, whereby the EV is able to put electricity on the grid and contribute to load management. Moreover, the production of renewable energy will have to be ramped up in Europe in order for the EVs to run with clean energy and to avoid the increase in emissions driven by the additional electricity demand. All this will require investments of at least Euro 240 billion by 2030, including the installation of charging points.[244] Part of the solution is the energy supply security, which

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[238] https://ev-top.com/ev-charger-manufacturers-spain/

[239] Nicholas M. and Wappelhorst S. (2021), Spain's electric vehicle infrastructure challenge: How many chargers will be requires in 2030?, WP 2021-03, International Council on Clean Transportation

[240] By contrast, China has 7 EVs per charging station and 3.8 kW per EV, along with 40% of fast charging stations.

[241] Global electric vehicle outlook 2022, https://www.iea.org/reports/global-ev-outlook-2022

[242] https://ev-top.com/ev-charger-manufacturers-spain/

[243] Global electric vehicle outlook 2021, https://www.iea.org/reports/global-ev-outlook-2021

[244] https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/europes-ev-opportunity-and-the-charging-infrastructure-needed-to-meet-it

can be fulfilled by a good interconnection with the rest of the EU countries. At the moment, Spain is still below the target of 10% interconnection ratio[245] set by the EU in 2002 and it only reached 4% in 2022.

The grid will also have to be able to support fast-charging stations on the high-ways in order to serve long-distance travel. Moreover, the charging stations will need to be inter-operable, to communicate with one another and to be connected to aggregators that pull together the EVs in order to make possible vehicle-to-grid operations. This will require coordination between the operators of the charging stations and the electricity providers. Finally, the charging stations will need to be connected to a payment system. This requires both investment and labour, sometimes with specific skills, for building and maintaining this infrastructure. Importantly, unprecedented enabling legal framework will need to be developed to allow for the operations described above.

Thus, the operation and maintenance of both charging stations and the electricity grid will require work force with potentially a new set of skill. The jobs that will be lost in the vehicle manufacturing, can be transferred to the set-up and maintenance of this new infrastructure.

5.2 Enabling factors for the electric mobility value chain

During the interviews with stakeholders, there were several challenges related to enabling factors for the electric mobility value chain, namely:

- **Investments needs for the transformation of the industry are very high**, especially in relation to the current size of the electricity market, which still remains relatively small. In Spain, the PERTE VECs did not have the desired impact, because they did not have the necessary flexibility with regards to (i). timing, (2) they were aimed at large tractor companies, they left out a significant number of Spanish SMEs more closely linked to light electric vehicles; and (3) the guarantees required from SMEs made them inaccessible to SMEs.
- Regarding the financial incentives to end-consumers consumer, stakeholders noted that current Spanish **subsidies in place for the purchase of electric vehicles require the buyer to have full financing prior to the purchase**, because the incentive is received later (even one or two years later).
- **Need for regulatory harmonisation:** regulations on electric mobility differ from one municipality or Autonomous Region to another (e.g. the law on "low emission zones", or the use of helmets on scooters).
- **Long permitting processes:** authorisations to implement charging points can take more than a year. Industry stakeholders call for the creation of one-stop shops to reduce the workload and timeframes for obtaining authorisation.

5.3 Barriers for electric mobility in Spain

This section summarized the main barrier identified through desk research an interviews regarding electric mobility in Spain.

- **Availability of charging stations**. Spain needs to increase the availability of publicly available charging stations, including for long distance travel. Along with the development of the physical infrastructure, the state has to put in place the legal framework for its operation in terms of

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[245] The interconnection ratio is defined as the sum of import capacities relative to installed generation capacity; https://www.vectorenewables.com/en/media-en/blog/spanish-electricity-system

communication of the charging stations/network with the grid, but also within the charging stations network and with the EVs to ensure smart charging and load management. Moreover, Spain could take more steps in promoting the manufacturing of charging stations in the country.

- **Reinforcing the electricity grid.** For a fully operational charging infrastructure, investments are needed for strengthening and expanding the transmission and distribution networks in order to satisfy the demand and offer technical solutions for bi-directional charging.[246] For this, investments in the digitalization of electricity networks are crucial. Again, an enabling and completely new legal framework to ensure the maintenance and operation of the grid and of the charging stations connected to it is required. Additionally, strong cooperation and partnerships between the grid operators and the owners of the charging networks would be needed to manage the bidirectional charging. This relation would also need to be regulated.
- **Sufficient and sufficiently skilled labour**. The transition to EM will create job displacement in the vehicle manufacturing industry. However, there will also be a need for skilled labour to build the necessary infrastructure to support the uptake of EM. Therefore, Spain has to already anticipate all these changes in the labour market and establish appropriate measures for re-skilling, re-training and, ideally, facilitate inter-sector mobility of the country's work force. In particular, Spain has to reinforce and promote vocational training to increase the number of professionals and to retain the existing ones. In fact, during the interviews conducted with the stakeholders (two professional associations and three companies), it became clear that already in the present there is a problem of skills shortage in the EV industry and that this is expected to continue in the future based on the planned growth path. Our interviewees pointed to the fact that the universities do not supply a sufficient number of people with the required skilled to fill the necessary vacancies in the industry. At the same time, there is a shortage of professionals such as installers, electricians, handlers of cables and interconnections, digitalization experts and personnel to manage the charging infrastructure, which could be prepared through vocational training. Thus, the interviewed stakeholders recommend the creation of more education and training programmes to increase the number of professionals and to retain the existing ones through re-training, re-skilling or even skills conversion. At the same time, the state should promote STEM careers to hight-school students, and promote these careers amongst women, in order to increase the number of students in technical universities.

5.4 Mapping of existing initiatives related to electric mobility.

In the area of mobility, Spain has launched several programs in the framework of the MRR under the umbrella of MITERD and IDAE:

- **PERTE VEC** [247]: *"PERTE para el desarrollo del Vehículo Eléctrico y Conectado"*. The objective of this PERTE is to develop the Spanish ecosystem of electric and grid-connected vehicles, turning Spain into the European Hub for electromobility. This project is focused on strengthening the value chains of the Spanish automotive industry, a strategic sector for Spain. Some grant-based programs developed under this PERTE are listed below:

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[246] Bi-directional charging means that the stations must communicate not only with the grid, but also with each other and be inter-operable.

[247] PERTE VEC. https://www.mincotur.gob.es/es-es/recuperacion-transformacion-resiliencia/paginas/perte.aspx

- **Efficient and sustainable mobility**: *"Plan MOVES II & MOVES III"* [248]. This program supports the acquisition of electric vehicles, the implementation of charging infrastructure as well as other actions related to mobility.
- **Electrification of light vehicle fleets**: "*Programa MOVES FLOTAS*" [249]. The MOVES FLOTAS program finances electric vehicle purchase and the installation of charging points as part of electrification projects of companies. The three programs mentioned, MOVES II, MOVES III and MOVES FLOTAS, are directly linked to one of the barriers identified, as they promote the availability of charging stations by financing the installation of new points.
- **Singular projects in electric mobility:** "*Programa MOVES Singulares II*" [250]. The projects financed under MOVES Singulares II must present a significant degree of innovation and raise the level of environmental protection. Actions must be related to electric mobility, charging infrastructure, development of new processes, etc. This program is associated to the barrier identified reinforcement of the electricity grid, as financing is offered for increasing the charging efficiency or the implementation of smart grids.
- Additionally, the Spanish Government has approved an initiative to digitalize electricity distribution networks and promote charging infrastructure for electric vehicles on public roads, providing financial support to distribution companies in the frame of the MRR (C8.I2 Network digitalization)[251] and implemented the Tecnological Automotion Plan for Sustainable Automotion to promote private sector RD&I [252].

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[248] Plan MOVES II. https://www.idae.es/ayudas-y-financiacion/para-movilidad-y-vehiculos/plan-moves-ii
Plan MOVES III. https://www.idae.es/ayudas-y-financiacion/para-movilidad-y-vehiculos/programa-moves-iii

[249] Programa MOVES FLOTAS. https://www.idae.es/ayudas-y-financiacion/para-movilidad-y-vehiculos/programa-moves-flotas

[250] Programa MOVES Singulares II. https://www.idae.es/ayudas-y-financiacion/para-movilidad-y-vehiculos/programa-moves-proyectos-singulares-ii

[251] https://www.idae.es/noticias/el-gobierno-destina-525-millones-digitalizar-las-redes-de-distribucion-e-impulsar-la

[252] https://www.ciencia.gob.es/Noticias/2021/Julio/El-CDTI-lanza-la-convocatoria-del-Programa-Tecnologico-de-Automocion-Sostenible-con-40-millones-de-euros-en-subvenciones.html;jsessionid=28C4AD3B98B930C4CED128EE4E8E7B0B.2#:~:text=El%20CDTI%2C%20entidad%20p%C3%BAblica%20adscrita%20al%20Ministerio%20de,la%20transici%C3%B3n%20al%20veh%C3%ADculo%20cero%20emisiones%20y%20conectado.

6 Hydrogen

Hydrogen and its derivatives[253] are promised to play an important role in the decarbonization of the global economy. Hydrogen has a variety of applications in mobility, industry and energy. Current interest in hydrogen and its derivatives is dominated by four main drivers:

- Pressure to reduce emissions from mobility and industry sectors
- Large costs of infrastructure for high e-mobility shares, for example for charging stations and grid infrastructure expansion.
- Storage of variable (excess) electricity
- Efficient repurposing of existing infrastructure of gas pipelines systems and storages

Hydrogen may be produced through a variety of processes. These production pathways are associated with a wide range of emissions, depending on the technology and energy source used and have different costs implications and material requirements. These are[254]:

- **'Electricity-based hydrogen'** refers to hydrogen produced through the electrolysis of water (in an electrolyser, powered by electricity), regardless of the electricity source.
    - 'Renewable hydrogen' is hydrogen produced through the electrolysis of water (in an electrolyser, powered by electricity), and with the electricity stemming from renewable sources. Renewable hydrogen is also known as 'green hydrogen'.
- **'Fossil-based hydrogen'** refers to hydrogen produced through a variety of processes using fossil fuels as feedstock, mainly the reforming of natural gas ("gray hydrogen") or the gasification of coal ("brown hydrogen"). This represents the bulk of hydrogen produced today. If the greenhouse gases emitted as part of the hydrogen production process are captured, the hydrogen is also known as 'blue hydrogen'.

The European Commission published its EU hydrogen strategy[255] and EU Energy System Integration Strategy in July 2020[256], which provides guidelines for policy and regulatory support of hydrogen. Updated by the REPOWEREU action plan, the Commission aims to produce 10m tons and import 10m tons of renewable hydrogen in the EU by 2030.[257] This equates to 65-80GW of electrolyser capacity, and the EC has already signed a joint declaration with the primary electrolyser manufacturers to boost production of electrolysers to 25 GW per year by 2025.[258]

In October 2020, the Spanish government presented its hydrogen roadmap "Hydrogen Roadmap: A Commitment to Renewable Hydrogen"[259] consistent with the targets set by the EU Hydrogen Strategy. On the production side, the roadmap sets the objective to reach 4 GW of installed electrolysis power by 2030. A short-term target of 0.6 GW has been set for 2024. On the consumption side, the roadmap sets a 25% target for renewable hydrogen use in industry by 2030. The hydrogen produced will be of special interest for those sectors that are difficult to decarbonize, such as the metallurgical and chemical sectors, and to promote sustainable mobility by means of hydrogen-consuming vehicles.

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[253] refers to a variety of gaseous and liquid fuels synthesized with hydrogen and carbon
[254] COM/2020/301 final
[255] COM/2020/301 final
[256] COM(2020) 299 final
[257] SWD/2022/230 final
[258] European Clean Hydrogen Alliance (2022), Joint Declaration
[259] https://www.miteco.gob.es/es/ministerio/hoja-de-ruta-del-hidrogeno-renovable.aspx

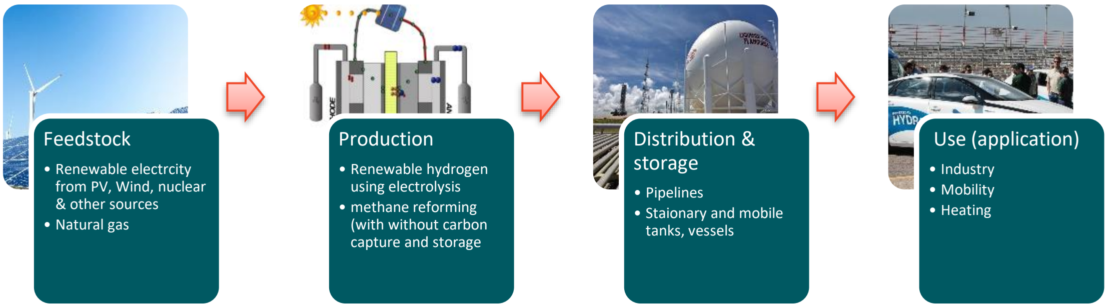
According to the EU hydrogen strategy, priority is given to develop **renewable hydrogen**, produced using mainly wind and solar energy[260]. The EU wants to build on the experience in industrial level **electrolyser** production to create new jobs and foster economic growth within the EU and support a cost-effective integrated energy system[261]. The Spanish hydrogen roadmap also underscores that, by 2030, there will be an acceleration in production and application of renewable hydrogen in Spain that is competitive with other production technologies. In addition, the roadmap foresees that Spain could become a major renewable hydrogen exporter to the rest of Europe. Therefore, the focus of this value chain analysis is on renewable hydrogen.

6.1 Hydrogen value chain at the EU level

The hydrogen supply chain consists of the following steps (see Figure 6-1):

1. **Feedstock:** This is the energy and/or material used to produce hydrogen. For renewable hydrogen, the value chains related to this part (mainly solar and wind power) are reviewed in other parts, so they are not reviewed here.
2. **Production:** This refers to the production of the hydrogen itself, where in the case of renewable hydrogen this is electrolysis.
3. **Distribution and storage:** This refers to the gas infrastructure needed for distribution of the hydrogen over land, sea, and air, and the infrastructure needed for storing the hydrogen for later use. As this subject is covered in the storage section, it will not be covered once again here.
4. **Use:** The basket of technologies that can use hydrogen usually by a) burning the hydrogen, b) using the hydrogen within a chemical process, and/or c) using the hydrogen within a fuel cell. The less mature technology whose dependencies are commonly relevant are fuel cells.

Figure 6-1 Hydrogen value chain



Considering the dependencies in the hydrogen value chain, in this text we will mainly look at electrolysers (in the production step) and fuel cells (in the use step).

6.1.1 Electrolysers

There are currently three main types of hydrogen electrolysers:

1. **Alkaline electrolysers** are mature electrolysis technologies that electrolyze water in an alkaline electrolyte solution. These electrolysers have been in use since the 1920s, mainly within the chlor-alkali industry, mostly to produce chlorine; however, their application to produce

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[260] COM(2020) 301 final
[261] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0301&from=EN

hydrogen as a main product has been more expensive than fossil-based methods and are seldom used. Globally, these electrolysers produced 35kt of hydrogen in 2021 with 500MW of capacity.

2. **Proton Exchange Membrane (PEM) electrolysers** use a solid polymer electrolyte (which performs better than the alkaline solution in alkaline electrolysers) produce hydrogen. However, the technology is less mature than alkaline technologies, and thus more expensive.
3. **Solid Oxide Electrolysis Cells (SOEC)** are still in an experimental stage, but hold much promise for use in the future. SOECs can operate at high temperatures and some can be reversed to consume hydrogen as fuel cells.

The main components of the electrolysers value chain include:

Studies, assessments and engineering

Building electrolysers facilities require several studies and positive assessments prior to the project authorization. Among various permitting issues, these projects need a positive Environmental Impact Assessment. For design and engineering, these include the technical designs of the connection to power sources (e.g. the grid), electrolysis plant layout including hydrogen cleaning unit and local storage tanks, calculations of the hydrogen production, definition of a budget and schedule for the construction project, together with supporting analysis. This stage might include synergies with other sectors, such as construction, civil works, naval construction, etc. Considering Europe's strong historical manufacturing capacity in this technology, and the global leadership of European companies producing electrolysers, these studies and assessments are well-developed in the EU.

Raw materials

The raw material requirements of different electrolyser technologies are different:

a. Alkaline electrolysers use few precious metals and minerals. These include nickel, zirconium, steel, and aluminium, at quantities far lower than those expected from other energy technologies (such as batteries).[262]

b. PEMs require titanium and some platinum group metals (PGMs[263]), mainly platinum and iridium.[264] Europe's high import dependency for these metals are a primary reason why they are considered critical in the EU's Critical Raw Materials list.[265] However, some experts believe that the use of these materials in electrolysers will drop dramatically (by 90%) in the coming years.[266]

c. SOECs use nickel, zirconium, and two rare earth elements (lanthanum and yttrium). Of these materials, the REEs are considered critical in the EU context due to high import dependency.[267]

Overall, Europe is fully dependent on the supply of 19 of 29 raw materials relevant to electrolysers (and fuel cells), and also relies on several critical raw materials for various renewable power generation technologies[268].

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[262] IEA (2022), The Role of Critical Minerals in Clean Energy Transitions

[263] Platinum, iridium, palladium, rhodium, and ruthenium.

[264] Trinomics (2021), Study on the resilience of critical supply chains for energy security and clean energy transition during and after the COVID-19 crisis

[265] European Commission (2020), Study on the EU's list of Critical Raw Materials.

[266] IEA (2022), The Role of Critical Minerals in Clean Energy Transitions

[267] European Commission (2020), Study on the EU's list of Critical Raw Materials.

[268] COM(2020) 301 final

Manufacturing

There are several components that are similar across the three electrolyser types, including compressors, water purification, dryers and electrical systems. However, they also have some significant differences within the electrolyser stack, due to different materials and manufacturing processes used. A recent study by ARUP, presents detail list of components for the three electrolyser types.[269]

- For alkaline electrolysers, Europe is a large manufacturer. components can generally be sourced within Europe.[270] Most of the components used in anode, cathode and bipolar plates are more-or-less standard industrial materials, produced to the specifications of the system integrators. The diaphragm materials are crucial for performance and although standard materials exist, some system integrators use their own proprietary designs.
- The PEM electrolysis supply chain shares some similarities with its alkaline counterpart as far as system components are concerned, though since there is no liquid electrolyte to be pumped and filtered, the PEM balance of plant is simpler. The main cost contributors to the system are the stack (40%-60%), followed by the power electronics, with titanium-based bipolar plates and meshes. Many 20MW PEM facilities are in development in Europe, but it remains a smaller actor in this industry than with alkaline electrolysers.[271]
- The SOEC electrolyser stack also uses a simple design due to having a solid electrolyte. SOEC manufacturing is still in a nascent stage, so cost predictions are imprecise and manufacturing capacity remains low.

Currently, Europe holds about 25% of electrolyser manufacturing capacity (mostly in alkaline electrolysers) and has overall a strong presence in the electrolysers value chain. Many European companies have announced plans to develop more electrolyser production capacity in Europe, including ThyssenKrupp Nucera, Nel Hydrogen, John Cockerill, Sunfire, Siemens, McPhy, and Topsoe. Overall, current announced capacities (25 GW per year by 2025) are still below what is generally aimed for by the EU's hydrogen plans announced under REPowerEU (65-80 GW per year by 2030).[272]

Despite Europe's strong presence in this sector, stakeholders stressed in interviews that this position can potentially deteriorate in the future. Other regions are strongly pushing the development of hydrogen manufacturing, and European manufacturers are at risk of not scaling quickly enough to compete. One example to consider is the case of the US, which recently implemented a plan for green hydrogen manufacturing involving investments of $8 billion to create regional green hydrogen plants, $1 billion for electrolysis technology and $500 million for green hydrogen recycling projects. Thus, **Europe should implement a comprehensive support plan as soon as possible, otherwise companies from other countries (such as the US) will develop faster and competitiveness will be lost**.

Transport, distribution, and installation

Electrolysers are generally large and difficult to move devices. These devices are usually manufactured and installed in close proximity, and are rarely traded globally.[273] With Europe's strong presence in the electrolyser manufacturing industry, it also has large-scale capabilities in logistics and installation.

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[269] ARUP(2022). Assessment of Electrolysers, final report

[270] E4tech (UK) Ltd for FCH 2 JU in partnership with Ecorys and Strategic Analysis Inc. (2019). Study on Value Chain and Manufacturing Competitiveness Analysis for Hydrogen and Fuel Cells Technologies (FCH contract 192) – Evidence Report.

[271] E4tech (UK) Ltd for FCH 2 JU in partnership with Ecorys and Strategic Analysis Inc. (2019). Study on Value Chain and Manufacturing Competitiveness Analysis for Hydrogen and Fuel Cells Technologies (FCH contract 192) – Evidence Report.

[272] IEA (2023), Energy Technology Perspectives 2023

[273] IEA (2023), Energy Technology Perspectives 2023

Operation and Maintenance

Electrolysers can operate for about 25 years, during which they require regular maintenance by skilled chemical and electrical engineers. Electrolyser stacks typically have shorter lifespans (7-10 years for alkaline and PEM systems, 2-3 years for SOEC) and would demand more frequent replacement.

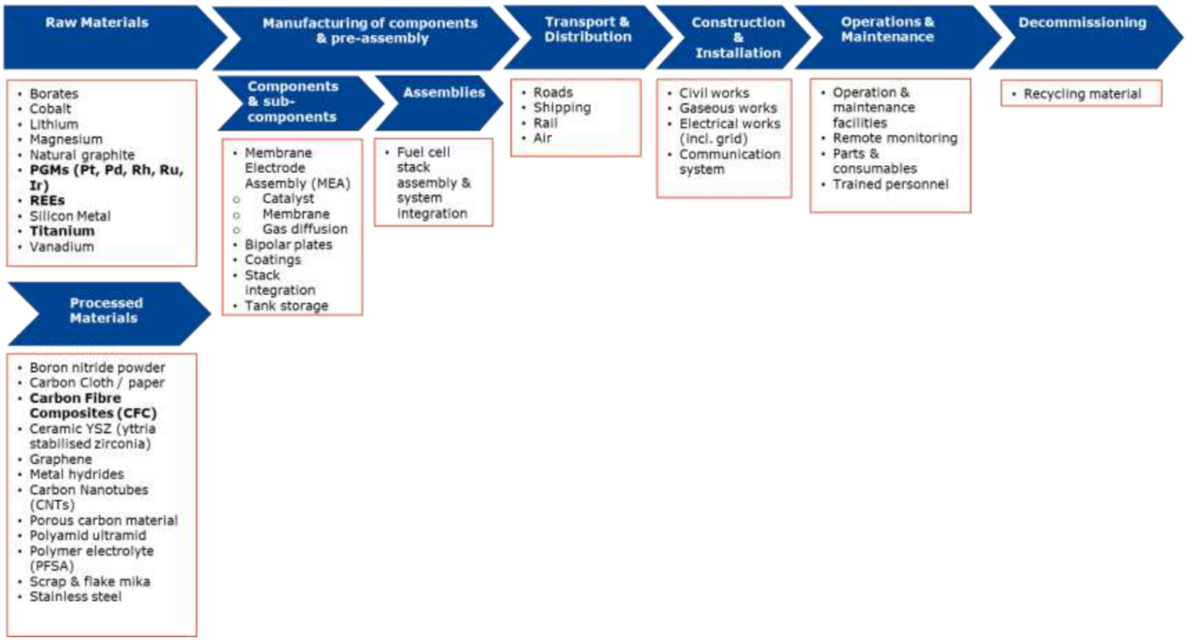
Decommissioning and recycling

The frequent replacing of electrolyser materials and full stacks during the lifetime of an electrolyser leads to a large store of material available for recycling. Recycling the precious metals within the stack is especially necessary to ensure a sustainable hydrogen economy. Europe already holds a strong position in this regard, with over 50% of its base metals supply coming from secondary (recycled) sources.[274] The European Raw Materials Alliance aims to further boost recycling innovation and capacity, especially for the EU’s critical materials.

6.1.2 *Fuel cells*

Hydrogen fuel cells convert hydrogen and oxygen gas into electrical energy and water through a chemical process, without combustion. It acts as the reverse of an electrolyte and involves the same components – a cathode and an anode surrounded by an electrolyte. Several types of fuel cells are currently available, “based on the type of fuel used, operating temperature, and the type of electrolyte: Polymer Electrolyte Membrane FC (PEMFC) ; Phosphoric Acid F (PAFC) ; Alkaline FC (AFC) ; Molten Carbonate FC (MCFC) ; Solid Oxide FC (SOFC) ; Direct-Methanol FC (DMFC).”[275] PEMFCs are the most common technology, due to their use in the automotive sector. The hydrogen fuel cell value chain and its material and technological dependencies are detailed in a prior Trinomics study, summarized in Figure 6-2.[276]

Figure 6-2 - Hydrogen fuel cell value chain and vulnerable elements. Source: Trinomics (2021)[277]



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[274] IEA (2022), The Role of Critical Minerals in Clean Energy Transitions

[275] Trinomics (2021), Study on the resilience of critical supply chains for energy security and clean energy transition during and after the COVID-19 crisis

[276] Trinomics (2021), Study on the resilience of critical supply chains for energy security and clean energy transition during and after the COVID-19 crisis

[277] Trinomics (2021), Study on the resilience of critical supply chains for energy security and clean energy transition during and after the COVID-19 crisis

These steps (and specific context at the European level) are:

1. **Raw and processed materials.** The materials used for fuel cells are the main value chain bottleneck from a European perspective. Since fuel cells use the same technologies as electrolysers (PEM and SOFC), their critical materials usage is somewhat similar. For raw materials, PGMs, titanium, and some REEs are also materials for fuel cells which are considered critical in the EU context.[278] As fuel cells replace internal combustion engines in the automotive sector, they will also replace some of the critical material use there. This is especially relevant for PGMs, which are also used in the catalytic converters of ICE vehicles, and less use here will partially make up for the additional demand of PGMs. For processed materials, similar to electrolysers, Europe is the major supplier of these materials for fuel cells (40%).[279]
2. **Manufacturing of components.** Unlike electrolysers, Europe is a less prominent participant in the fuel cells industry. Nonetheless, the region is partially active in producing components for fuel cells, such as bipolar plates and membrane electrode assemblies, and provides about 25% of the global supply.[280]
3. **Assembly.** Europe lags behind other regions in production of fuel cells but is catching up. Multiple companies have announced plans to develop fuel cell manufacturing capacity in Europe, including Symbio in France, planning for 200.000 automotive fuel cells by 2030.[281]
4. **Transport and distribution.** Various parts of the value chain require transport and distribution capabilities. In this regard, Europe's mature position in this industry and other relevant industries gives the region strong capabilities in logistics infrastructure throughout the value chain.
5. **Construction and installation.** A main use of fuel cells is in the automotive sector, as part of FCEVs. In this context, many automotive companies have announced plans to rapidly scale manufacturing of FCEVs in Europe, including Nikola and Daimler. The focus of these automotive producers are mostly in the heavy-duty trucking sector.[282]
6. **Operations and Maintenance.** Similar to electrolysers, the operations and maintenance of fuel cells will require labour skilled in chemical and electrical engineering disciplines.
7. **Decommissioning and recycling.** The replacement and recycling of fuel cell components will require the development of a full supply chain surrounding retrieving the most important components and raw materials in fuel cells. The PGMs can especially be promising here, as some experience with their recycling exists (partly within catalytic converters for internal combustion engines).

Fuel cells would primarily find usage in the automotive sector, especially in settings where the range and weight limitations of the clean alternative – battery EVs – becomes important. This is especially the case with heavy-duty long-haul trucks. However, with recent competition from battery-powered options, the future demand for fuel cells within trucks and in the automotive industry more broadly in general is highly uncertain.

6.2 Mapping the Spanish value chain for renewable hydrogen

Spain produced and consumed 500 000 tons of hydrogen in 2022, which was mainly produced via grey hydrogen methods. This hydrogen was mainly used as feedstock for refineries (70%) and for the production

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[278] European Commission (2020), Study on the EU's list of Critical Raw Materials.

[279] Blagoeva, D., Pavel, C., Wittmer, D., Huisman, J. and Pasimeni, F. (2019). Materials dependencies for dual use technologies relevant to Europe`s defence sector, EUR 29850 EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-76-11101-6, doi:10.2760/279819, JRC117729

[280] Trinomics (2021), Study on the resilience of critical supply chains for energy security and clean energy transition during and after the COVID-19 crisis

[281] IEA (2023), Energy Technology Perspectives 2023

[282] IEA (2023), Energy Technology Perspectives 2023

chemical (25%). In the coming years, the Spanish government has strong ambitions to become a forerunner in Europe in the hydrogen industry. The government envisions the development of large-scale renewable hydrogen production projects over the coming years, accompanied by proportional investment in infrastructure projects for the transport, distribution and trade of hydrogen use. Hydrogen is foreseen as the main future energy vector in many use-cases, including high temperature industrial processes, long distance transport (freight, maritime, and aviation), and energy storage.

The hydrogen roadmap, released in 2020 by the Spanish government, aims for "*Developing the value chains of the hydrogen economy. The hydrogen economy must be driven and supported by the development of the associated industrial and energy value chain, such as manufacturers or assemblers of electrolysers, fuel cell manufacturers, component manufacturers (electronics, control, automotive, mechanical), vehicle manufacturers, shipyards, pressure vessel suppliers, suppliers of integral systems such as hydrogen fuel stations or renewable hydrogen production plants, as well as their management, large-scale storage solutions, hydrogen transport equipment, renewable hydrogen-based mobility service providers, etc.*" In addition, the roadmap aims for "*the promotion of innovation and growth of the industry, creating conditions that are conducive to the generation of wealth and the creation of highly qualified jobs at each stage of the renewable hydrogen value chain*." The hydrogen roadmap aims to abate 4.6 Mt of CO_2 emissions by installing 600 MW of electrolysers by 2024 and 4 GW in 2030. In addition, it aims to supply 25% of industrial consumption with green hydrogen by 2030. Following this roadmap, in 2021, the Spanish government launched PERTE aid amounting to €1.5 bn to develop hydrogen technology. Since the release of the roadmap, several projects related to renewable hydrogen have been initiated (see some example projects in Table 6-1 ; a list can be found in [283]).

Spain's future hydrogen plans depend on two pillars: 1) hydrogen production, and 2) hydrogen transport and storage. The METIS 3 study of the pan-European hydrogen infrastructure predicts that by 2030, Spain will produce 45% (2.3 Mt) of the EU's 5 Mt hydrogen demand.[284] This comprises 1.6 Mt of hydrogen exports, which depends on the existence of transport infrastructure.[285] A similar plan by the European Hydrogen Backbone also makes strong predictions about hydrogen production in Spain (12 Mt/y by 2030, of which 7.7 Mt is green hydrogen, while the remainder is from grid electricity and blue hydrogen).[286] Both plans assume the development of a pan-European hydrogen pipe network, especially a pipeline connecting Spain to France and onto Germany, supplying heavy industry there and along the pipeline. Storage, especially within salt caverns, are also needed to keep hydrogen for long time periods and balance supply and demand fluctuations.

Thus, we discuss here the primary aspects relevant for Spain, which is hydrogen production – namely electrolysers.

6.2.1 *Electrolysers*

Spain has very strong ambitions regarding hydrogen production in the coming years. As part of the PERTE funds, over 30 applications were made for funding for electrolysers, with over half connected to a renewable electricity source. Some of these projects that also include renewable electricity production

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[283] Serna, S. et al. (2022). Annual report chair for low carbon hydrogen studies 2021 – 2022

[284] It is worth noting that RePowerEU has revised the EU's hydrogen ambitions to 10Mt per year imported and 10Mt per year produced internally.

[285] METIS 3 - Study S3 METIS study on costs and benefits of a pan-European hydrogen infrastructure – In assistance to the impact assessment for designing a regulatory framework for hydrogen

[286] NTTData (2022), Support to RePowerEU: In-depth support on priority area "Estimation of Spain's H2 contribution to REPowerEU"

are listed in Table 6-1 . An especially ambitious project in this space is the HyDeal España project, developed by a consortium of 30 companies. By 2030, the project aims to supply an industrial cluster in Asturias with hydrogen, made from 9.5 GW of solar power and 7.4 GW of electrolysers. The project also aims to develop a gigafactory for electrolyser manufacturing.[287]

Table 6-1 List of renewable hydrogen projects[288]

Project	Electricity production capacity (MW)	Electrolyser capacity (MW)	Production capacity (tons/year)	Value chain	developer	Investment
Photovoltaic plant with hydrogen production and consumption in Asturias[289]	9500	7400	-	Production and consumption	HyDeal España (PlatformCo Hidrogeno)	No information
Photovoltaic plant with hydrogen production[290]	400	60	~9000	Production and storage	Enagás and Naturgy	No information
23 renewable hydrogen projects [291]	2000	340	-	Production & storage	Edesa	€2.9bn
PV plant with hydrogen production project[292]	100	20	3000	Production	Iberdrola	€150m
Photovoltaic plant with hydrogen production in Vizcaya[293]	20 initial, 200 by 2030	(Not stated)	1500	Production	White Summit Capital, Castleton Commodities International (CCI), Nortegas, SENER, Bizkaia Energia	€50m (initial investment), €300m (final investment)

Overall, Spain already has a portfolio of 15.5GW of green hydrogen projects "in the pipeline". These projects are already almost quadruple Spain's ambitions in its hydrogen strategy of 4 GW of electrolyser capacity by 2030. However, developing this installed capacity requires a strong push in developing the electrolyser value chain in Spain and other measures to reach a final investment decision for the projects. Many of the potential challenges with the hydrogen value chain in Spain mirror those at the EU level:

1. **Studies, assessments and engineering:** Spain has a very strong base in academic and research institutions regarding the development of hydrogen and related technologies. However, there is still a "valley of death" between the developed technology and the large-scale manufacturing of that technology in Spain. Experts indicate that this is a historical challenge with Spanish knowledge transfer between academic institutions and production companies. they are unable to place it on the

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[287] https://www.hydeal.com/copie-de-hydeal-ambition
[288] https://www.wfw.com/articles/the-spanish-hydrogen-strategy
[289] https://www.hydeal.com/copie-de-hydeal-ambition
[290] https://energetica21.com/noticia/enagas-y-naturgy-impulsan-en-leon-la-mayor-planta-de-hidrogeno-verde-de-espana
[291] https://www.endesa.com/es/prensa/sala-de-prensa/noticias/transicion-energetica/endesa-contempla-desarrollo-23-proyectos-hidrogeno-verde-espana
[292] https://www.iberdrola.com/about-us/what-we-do/green-hydrogen/puertollano-green-hydrogen-plant
[293] https://cincodias.elpais.com/cincodias/2020/12/03/companias/1606994631_808226.html

market because the calls for proposals often require other similar products or facilities to be in operation.

2. **Raw and processed materials:** Similar to the EU level, titanium and PGMs will be critical materials for the electrolyser value chain in Spain. Much of these metals come from extra-EU sources, and Spain lacks mining and refining capacity to meet its demand in the coming decades.
3. **Manufacturing of components/assembly:** Previously, the production of components and assembly of electrolysers has been concentrated in other EU countries. The availability of technical know-how from other EU countries, and capital mobilized from both public support funds and private investment have boosted Spain's development of this manufacturing capability. Many new projects have been announced recently, including plans by Cummins to build one of the world's largest electrolyser manufactories. The plant's initial production capacity of 500 MW per year is expected to scale up to 1 GW per year.[294] Repsol, the largest hydrogen producer and consumer in Spain, also has planned multiple new hydrogen projects in the Basque country, Catalonia, and the Region of Murcia. The project HyDeal España also aims to develop a gigafactory for electrolyser manufacturing.[295] Developing a new electrolyser factory can be rather quick (2-3 years, less for capacity expansion of existing facilities)[296], so these capabilities can be expanded in time to meet Spain's ambitions in terms of hydrogen production.
    - Industry stakeholders also suggested that policymakers could encourage the integration into the green hydrogen chain of certain industries that already have a high degree of maturity in Spain. An example is the auxiliary automotive sector, where companies are experienced with manufacturing a machine with metal parts, plastic parts or electrical panels at scale.
    - A significant ongoing issue for Spanish green hydrogen projects, especially electrolyser development and deployment, is acquiring project finance. Stakeholders highlight that unlike wind or solar power projects, there is currently no project finance for green hydrogen projects. Financial institutions mostly lack the track record, experience and knowledge to grant funding for hydrogen projects. Specific to the PERTE program for hydrogen, experts highlight a "brutal" barrier in obliging SMEs to guarantee 100% of the advance payments. In this framework, SMEs cannot participate. The financial issue is absolutely critical for CAPEX-heavy green hydrogen, and to this end it is necessary to resolve the issue of guarantees, interest rates, and financing volumes.
4. **Transport, distribution, and installation:** Electrolysers are usually heavy and bulky devices, which are produced close to where they are installed and used.[297] Given Spain's maturity in logistics and installation of similar technologies, as with the EU level, little challenges are foreseen in this part of the value chain.
5. **Operation and Maintenance:** As mentioned earlier, electrolysers have a lifetime of 25 years, during which the electrolyser stack must be replaced multiple times (frequency depending on the stack's chemistry). The operation and maintenance of electrolysers will require developing a skilled workforce, primarily in chemical and electrical engineering. Spain has historically not had a significant presence in the electrolyser domain, so this will require significant upskilling in labour, to develop the capacities necessary for operating many GWs of electrolysers. As confirmed by experts, this labour shortage will be a significant challenge for Spain's short-term ambitions of rapidly expanding the hydrogen industry.

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[294] Hydrogen Europe (2021), Hydrogen.

[295] https://www.hydeal.com/copie-de-hydeal-ambition

[296] IEA (2023), Energy Technology Perspectives 2023

[297] IEA (2023), Energy Technology Perspectives 2023

A major barrier in Spain for the commissioning of green hydrogen production is the length of the environmental licensing period, which can take two and a half years. This is a very significant burden on a nascent and dynamic industry. In turn, these deadlines are practically incompatible with PRTR support, and lead to lower investments in green hydrogen projects.

6. **Decommissioning and recycling:** Following the lifetime usage of electrolysers, they will need to be decommissioned and their critical materials recycled. Electrolysers have a relatively longer life than some other technologies (although the electrolysis stack is replaced frequently). Nonetheless, in the long-term, Spain must develop technical capacity to retrieve crucial elements from electrolysers, especially PGMs within the electrolysis stacks.

6.3 Enabling factors for the hydrogen value chain

The objectives of the Spanish government, as set out in the Spanish Hydrogen Roadmap are ambitious, and consolidates the position of green hydrogen as a viable sustainable energy alternative, in the focus of Spanish public policy for the near future. There is increased interest on the exploitation of hydrogen in a productive way, however the industry is still facing several challenges regarding the related regulatory framework and access to finance.

- Industry stakeholders consider there is still uncertainty in the regulatory framework and required administrative capacity surrounding the production of renewable hydrogen.[298] Besides the length of the environmental licensing period, stakeholders interviewed expressed concerns about the current expertise and/or capacity from public administration officials (particularly at local level) to develop suitable support programmes tailored for green hydrogen. To tackle this, it is suggested to strengthen public administration know-how, especially at the local/Autonomous Region level.
- The uncertainty that still surrounds this technology is causing companies to be reluctant to invest in its development. As mentioned above, acquiring project finance is a significant problem for green hydrogen projects in Spain, particularly for electrolyser development and deployment. Financial institutions lack the experience and knowledge to grant funding for hydrogen projects. Access to finance is crucial for CAPEX-heavy renewable hydrogen, which could be supported in the form of guarantees, lower interest rates, and making available higher financing volumes to scale-up the deployment of the technology.
- Moreover, stakeholders expressed concern about the stringent deadlines set in the calls for proposals, asking for completion of projects in timelines that are significantly shorter than those required for larger projects. This was listed as one of the reasons why some companies chose not to apply for the PERTE calls.

6.4 Barriers in Spain for the hydrogen value chain

The desk research and industry stakeholders activity underlined that Spain has the capacity to play a leading role in the deployment of green hydrogen production for its national and international markets, due to potential for producing it in large quantities and at a competitive price. There is an increased interest from government and industry to develop this sector further, paired with a good RD&I

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[298] Energetica (2022). Habla el sector: entrevistas – Sector: Hydrogeno. Revista de Generación de Energía y Eficiencia Energética. Energética XXI 222 DIC22. Available at: https://energetica21.com/revistas-digitales/diciembre-2022

environment for hydrogen in Spain. However, the analysis conducted highlights latent barriers faced by industry to reach this potential.

The barriers identified via desk research and stakeholder engagement and related measures are summarized in Table 6-2. Overall, the most pressing challenges identified are related to the presence of critical raw metals (inc. titanium and PGMS) in electrolysers, difficulties in obtaining project finance and lack of skilled labour force for O&M of electrolysers .

Table 6-2: Summary of key barriers and needs identified per value chain segment

Value chain step	Value Chain segment affected	Barriers identified	Associated measures to accompany and boost the value chain
Production (Electrolysers)	Raw materials mining and refinement, processed materials	• High risks of supply for critical raw metals, including titanium and PGMs	• Improve recycling and circular economy through public support of pilot projects and RD&I activities, especially for critical materials • Create international partnerships with established electrolyser producers with reliable access to critical raw materials
Production (Electrolysers)	Manufacturing of equipment	• Project finance is difficult to obtain compared to other EU countries	• Establish guarantee mechanisms (funds) • Promote participation of Spanish companies in the association of electrolyser manufacturers
Production (Electrolysers)	Operations and maintenance	• Lack of skilled labour force for maintenance and operation of electrolysers	• Upskilling labour force to match increasing electrolyser capacity and develop mechanisms to retain talent
Production (Electrolysers)	Decommissioning, re-using, and recycling	• Missing capabilities for recycling critical materials and components	• Investments into RD&I efforts for recycling (critical) materials • Developing recycling capacities for critical materials, including PGMs and titanium
Transversal	Transversal	• Public administration officials (especially at the local level), often lack necessary expertise and/or capacity to develop suitable support programmes	• Strengthen public administration know-how, especially at the local/Autonomous Region level

6.5 Mapping of existing initiatives related to hydrogen.

Some of the most relevant initiatives developed by MITERD and IDAE under the MRR related to hydrogen projects are:

- **PERTE ERHA**[299]: *"PERTE de energías renovables, hidrógeno renovable y almacenamiento"*. National strategic project dedicated to boost investments in strategic sectors such as renewable energies, power electronics, hydrogen and storage. As part of this PERTE, three grant-based programs have been launched by IDAE and MITERD:

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[299] PERTA ERHA. https://planderecuperacion.gob.es/como-acceder-a-los-fondos/pertes/perte-de-energias-renovables-hidrogeno-renovable-y-almacenamiento

- **Pioneering hydrogen projects**: *"Programa H2 Pioneros"* [300]. The objective of this program is to promote the deployment of projects related to renewable hydrogen (including production, distribution, and consumption). Actions regarded under this program include installation of electrolysers, hydrogenerators and other initiatives linked to the barriers listed.
- **Hydrogen value chain**: "*Programas de incentivos a la cadena de valor innovadora y de conocimiento del hidrógeno renovable*" [301]. This program composed of four different calls, supports initiatives through the value chain of hydrogen, including manufacturing facilities and equipment, RD&I, large electrolysers, research challenges and training in key technologies.
- **IPCEI H2yTech:** "*Concesión directa de subvenciones a los proyectos españoles por su participación en el Proyecto Importante de Interés Común Europeo de tecnología de hidrógeno*" [302]. This initiative finances Spanish projects regarded as Important Projects of Common European Interest (IPCEI) that promote research and innovation as well as the first industrial use in the value chain of hydrogen.

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[300] Programa H2 Pioneros. https://www.idae.es/ayudas-y-financiacion/programa-h2-pioneros-ayudas-para-proyectos-pioneros-y-singulares-de-hidrogeno

[301] Programas Cadena de Valor del Hidrógeno. https://www.idae.es/ayudas-y-financiacion/programas-de-ayuda-la-cadena-de-valor-innovadora-del-hidrogeno-renovable-en

[302] IPCEI H2yTech. https://sede.idae.gob.es/lang/modulo/?refbol=tramites-servicios&refsec=proyectos-es-hy2tech

7 Heat pumps

For heat pumps a short introductory analysis is done that is less in-depth than other value chains.

Heat pumps are a technology that uses electricity to transfer heat from an outdoor or underground source to an indoor area. These devices typically depend on a refrigerant fluid for the transportation of the heat, and use its compression and decompression to release and absorb heat where needed, i.e. at specific indoor and outdoor/underground locations, respectively. This makes heat pumps a very energy efficient and important solution to decarbonize the built environment.

The heat source of heat pumps can be air (air-source heat pumps, with 80% market share), an outdoor water source (water-source heat pumps), or the ground (ground-source heat pumps). While gas and electric boilers depend on the energy of gas and electricity to create heat, heat pumps only use electricity to transport heat. This heat source is often a renewable and inexhaustible resource. Heat pumps usually have thermal efficiencies (amount of heat output divided by amount of energy input) of 300-500% and more than 3-5 times higher than boilers, given that their energy input is only used to transfer heat, rather than create it from the input energy. This is a key reason why heat pumps can lead to large energy savings and subsequent lower emissions. Despite their more expensive up-front costs (higher than fossil alternatives such as gas boilers), heat pumps can be a cheaper option during their lifetime due to their significantly lower energy demand (electricity).

Heat pump demand in Europe outpaces the rest of the world, with expectations of nearly 7 million devices installed based on policy objectives as of November 2022 (I.e. excluding the Net Zero Industry Act). [303] On the supply side, recent figures from the IEA indicate Europe will also continue to manufacture a very significant share of the global heat pump production. In the Net Zero Scenario, based on announced projects (as of April 4th, 2023), European production is predicted to reach 60 GW per year.[304]

7.1 Heat pump value chain and barriers in EU and Spain

Heat pumps already have a very mature value chain at both the EU and Spain level, as the core technology is almost identical to air cooling units. Globally, around 10% of the world's building heating needs are met by heat pumps, and Europe's demand for heat pumps is growing especially rapidly at 35% annually.[305] Many heat pumps and exiting HVAC systems can be reversed to provide both heating and cooling, as the refrigerant can be run in reverse to transport heat in the opposite direction. Reversible heat pump systems seem suitable for Spain, to deliver both heating needs in winter and cooling in summer.

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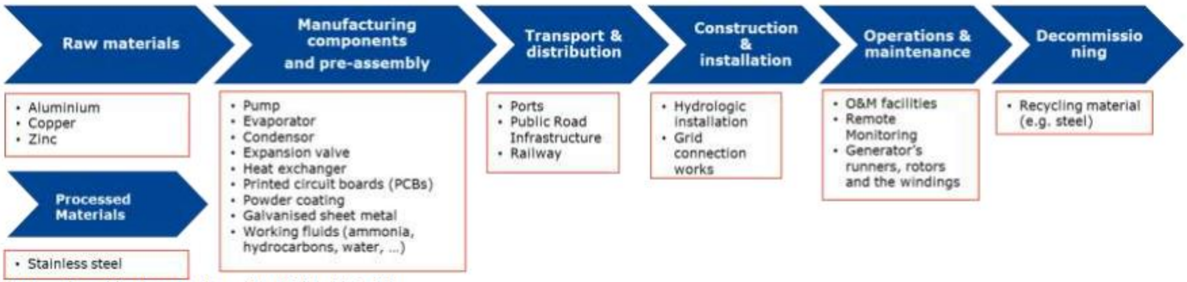
[303] IEA (2022), The Future of Heat Pumps

[304] https://www.iea.org/data-and-statistics/charts/heat-pump-manufacturing-capacity-by-country-or-region-according-to-announced-projects-and-in-the-net-zero-scenario (Accessed on April 18th, 2023)

[305] IEA (2023), Energy Technology Perspectives 2023

Figure 7-1 Overview of heat pump value chain. Source: Trinomics & Artelys (2021). Study on the resilience of critical supply chains.



Note: vulnerable elements found highlighted in bold

In the text below, we cover the value chain (see Figure 7-1) and combine some aspects of the value chain together for a summary mapping at both the EU and Spanish level.

7.1.1 Raw and processed materials and recycling and re-use

In terms of materials, the primary component with critical raw minerals in the heat pump is the compressor motor, which uses permanent magnets. Permanent magnets require rare earth elements (REEs) which are scarce. Rare earths are used far more extensively in wind turbine generators though. We refer to the discussion in the wind power chapter to cover rare earth elements and their dependencies in the Spanish context. Other than REEs, heat pumps use materials such as stainless-steel alloys, aluminium, copper, and zinc,[306] which are not considered as critical materials in the EU context.[307] Similarly, the recycling of permanent magnets into new uses, and the recovery of REEs from the magnets, is an important subject which is discussed in the wind turbines chapter.

7.1.2 Manufacturing components and assembly of heat pumps

A heat pump consists of many mechanical, chemical, and electrical components. The primary components are the compressor, electronics, heat exchanger, and the housing of the device, contributing to 25%, 23%, 15%, and 13% of the heat pump's overall costs, respectively.[308] Many components of a heat pump have highly mature supply chains, as they are manufactured for other devices as well, and evaporators, tanks, valves, and pumps are common across many supply chains. The heat exchangers and compressors of heat pumps, for example, are common in many air cooling units as well. For compressors, which make up about 25% of a heat pump's cost, Europe depends on imports for air-to-air heat pumps (which use an air source to also heat air). For other technologies (air-to-water and ground source heat pumps), Europe already has manufacturing capability for compressors, and can rapidly expand to manufacturing compressors for air-to-air heat pumps should the need arise. Europe has also high capacity in assembly of heat pumps. Thus, there is mature experience and high capacity for manufacturing and assembling heat pumps.[309] In fact, many companies have announced plans to dramatically increase manufacturing capacity in Europe within the next 3 years, including Vaillant, Daikin Europe, NIBE, Mitsubishi, Stiebel Eltron, Viessmann, and Panasonic.[310] For heat pumps, manufacturing dependence on countries such as China is far lower than other technologies, such as solar PV. Experts confirmed that Spanish companies are not (yet) large players in the EU heat pump market.

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[306] Trinomics (2021), Study on the resilience of critical supply chains for energy security and clean energy transition during and after the COVID-19 crisis

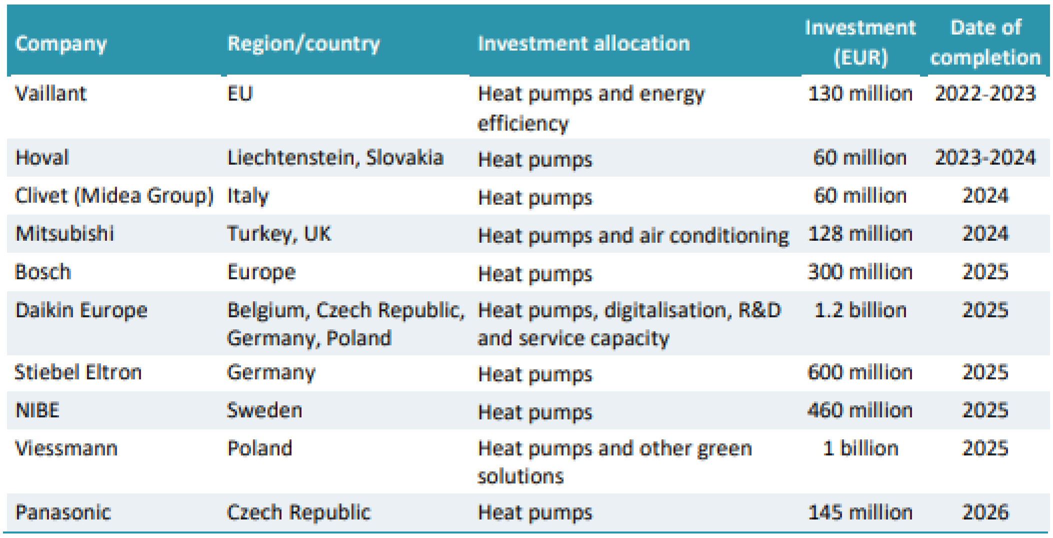
[307] European Commission (2020), Study on the EU's list of Critical Raw Materials

[308] Department for Business, Energy, and Industrial Strategy (2020), Heat pump manufacturing supply chain research project.

[309] IEA (2023), Energy Technology Perspectives 2023

[310] IEA (2022), The Future of Heat Pumps

Figure 7-2 Overview of new investments in the EU in heat pump manufacturing. Source: IEA (2022) The future of heat pumps.



Company	Region/country	Investment allocation	Investment (EUR)	Date of completion
Vaillant	EU	Heat pumps and energy efficiency	130 million	2022-2023
Hoval	Liechtenstein, Slovakia	Heat pumps	60 million	2023-2024
Clivet (Midea Group)	Italy	Heat pumps	60 million	2024
Mitsubishi	Turkey, UK	Heat pumps and air conditioning	128 million	2024
Bosch	Europe	Heat pumps	300 million	2025
Daikin Europe	Belgium, Czech Republic, Germany, Poland	Heat pumps, digitalisation, R&D and service capacity	1.2 billion	2025
Stiebel Eltron	Germany	Heat pumps	600 million	2025
NIBE	Sweden	Heat pumps	460 million	2025
Viessmann	Poland	Heat pumps and other green solutions	1 billion	2025
Panasonic	Czech Republic	Heat pumps	145 million	2026

Refrigerant fluid also creates some dependencies for Europe, which depends on Chinese and North American suppliers. The best-performing (compared to cost) refrigerant fluids have high global warming potential (such as R410A), but they are being quickly replaced by refrigerant with low global warming potential (such as R32 and propane). An expected update to the EU F-Gases Regulation is expected in 2024, which will give certainty to manufacturers regarding which refrigerants can be used. The proposed version of April 2022 of this regulation bans refrigerants with global warming potential of over 150311 for all self-contained and smaller split heat pump systems.[312] At least one industry interviewee indicated that this EU regulation can have a disruptive impact in the industry, especially given that production lines cannot adjust rapidly enough to the regulation's milestones.

7.1.3 Distribution and logistics

Heat pumps are generally made rather close to where they are later used, with the exception being some Chinese manufacturers that supply heat pumps to the global market. Europe and Spain have strong logistics and distribution networks that are already utilized for both heat pumps and similar technologies. This part of the supply chain would not be expected to become a critical challenge in the coming decades.

The international supply to Europe of some components, such as permanent magnets, refrigerant, and compressors also depends on international logistics infrastructure. Given the high maturity of the logistics infrastructure surrounding many of these materials and components, it is highly unlikely to create critical dependency for the EU in the coming decades. Although out of scope of this study, it is worth noting that heat pumps will lead to a significant increase in electricity demand on the distribution grid and can lead to the need for speeding up grid reinforcement.

7.1.4 Installation, maintenance, and operation

Installation, maintenance, and operation of heat pumps is also a mature market in Spain and the EU. Labour expertise from installing HVAC systems is already well-prepared for heat pump installations, with

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[311] The GWP is a metric used to compare the warming effects of various greenhouse gases over a specific timespan. It is defined as the multiple of CO_2 mass that can give the same amount of greenhouse effect as the material in question, and in most cases the timespan chosen is 100 years. For example, R-134a has a GWP of 1430, which means 1 kg of R134a has about similar global warming potential as 1550 kg of CO_2.

[312] See EC (2022). EU legislation to control F-gases for more info.

some additional skilling possibly necessary for the groundwork of ground-source heat pumps. IEA expects the labour needs for installation and maintenance of heat pumps in the EU to grow almost 3x from 2019 to 2030.[313] This growth matches the REPOWEREU targets for increasing trained installers from 40000 in 2019 to 130000 in 2030. Most installation and maintenance labourers can be upskilled from similar professions, including pipe fitters, plumbers, electrical technicians, and electrical mechanics. The number of workers that can be rapidly upskilled is vastly higher than the need, so the labour market is able to adjust rather quickly.[313] Thus, such labour supplies are not expected to become a big long-term issue. Nonetheless, it is worth noting the EU-wide shortage of workers in occupations relevant to heat pumps, such as pipe fitters, plumbers, electrical technicians, and electrical mechanics. Experts also indicated that vocational training needs to better adapt trainings to the real needs of the technology, and Spain also misses the industrial base (as is present in e.g. Germany) for relevant apprenticeships in companies.

Experts additionally highlighting some demand-side issues facing the heat pump industry in Spain. Financial support for the conversion to heat pumps on the demand side (households, businesses or institutions) has some aspects that prevent it from achieving the expected impact:

- Customers must go through a challenging and complex process to justify the need for and receive financial support for heat pump purchases/conversions;
- There is a lack of harmonisation in the aid application process between different Autonomous Regions, together with a lack of communication and dissemination of these aids.

7.2 Barriers for heat pumps in Spain

In order to survey the perspective of the main actors involved in the value chain associated with heat pumps, three interviews were conducted, one with an industry association and two with companies.

As a result from these interviews the main barriers identified for this technology's value chain are summarised as follows:

- **Heat pump production has little presence in Spain.** Most local equipment producers use components sourced internationally, from both European and non-European (primarily east Asian) sources. East Asian manufacturers have also set up or look to set up production in Europe and Spain. Two interviewees belonged a Spanish company, while the other represents a Japanese company which has plants in Europe, but only carries out marketing and after-sales service in Spain.
  Overall, there is an absence of heat pump manufacturing sites in Spain, which is deemed as a large barrier to the development of the value chain in Spain. While ground- and water-sourced heat pump manufacturing have room for growth in Spain, especially given the larger applications. The far larger air-sourced heat pump market is however more difficult to enter, due to the existence of large Asian producers who own patents on some components.
- **Challenging and complex financial support for consumers:** Support for the conversion to heat pumps involves financial support to the demand side (households, businesses or institutions), but this support has some aspects that prevent it from achieving the expected impact, paired with a complex process to obtain it. There are differences in the aid application process between the different Autonomous Regions, and a lack of communication and dissemination of these aids.

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[313] IEA (2022), The Future of Heat Pumps

- **Shortage of qualified personnel for heat pump installation:** the current vocational training offer has several shortcomings; for example, more specific training for heat pump installation (allowing HVAC installers to quickly transition into heat pump installation activities), developing training programs for rapidly growing technologies (such as air-to-water heat pumps) and increasing training programs for the complex tailoring and design of custom installations. Finally, the lack of industrial fabric in certain areas of Spain prevents internships in companies.

To overcome these barriers, stakeholders proposed the following measures:

- Adapt/improve financial aid for end-consumers of heat pumps, following the example of France or Italy. Particular points of improvement include:
    - make the conditions for the granting of aid more flexible, without weakening the control of aid;
    - harmonise the procedures and requirements of the different ACs; and
    - improving the dissemination of aid.
- Regarding vocational training, the key recommendations involve:
    - adapting the training catalogue to include skills specific to heat pumps installation and maintenance
    - informing society of the benefits of vocational training programmes
    - developing a long-term, coordinated, and continuous vocational training policy.

7.3 Mapping of existing initiatives related to heat pumps.

For the support of projects including heat pumps, two grant-based initiatives have been identified:

- **PREE 5000:** "*Rehabilitación energética de edificios en municipios de reto demográfico*" [314]. This program, focused on the promotion of energy rehabilitation and the reduction of final energy consumption and CO2 emissions in buildings, finances projects that include heat pump equipment, among other initiatives.
- **DUS 5000:** "*Ayudas para inversiones a proyectos singulares locales de energía limpia*" [315]. This program, structured in five diferent meassures, finances a wide range of actions regarding renewable energy. In particular, measure 3 supports projects that include heat pumps to cover at least the 80% of the heating and cooling demand.

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[314] PREE 5000. https://www.idae.es/ayudas-y-financiacion/para-la-rehabilitacion-de-edificios/programa-pree-5000-rehabilitacion

[315] DUS 5000. https://www.idae.es/ayudas-y-financiacion/programa-dus-5000-ayudas-para-inversiones-proyectos-singulares-locales-de

8 Conclusions on value chain barriers

In the previous chapters we have analysed the value chains for key technologies in detail. Based on the analysis and more than 20 conducted interviews, there are several conclusion we can draw.

While there is evidently room for improvement, **clean technology value chains and related policy have been quickly and positively developing in Spain since 2018**. This was also stressed in interviews, in particular for solar PV. Moreover, the current political situation both nationally and in the EU present both the political and financial space to further tackle many of the barriers mentioned in this report.

The **main barriers identified are not technology-specific and impact all value chains**, both in Spain and in the EU. This also indicates that a coordinated, **overarching approach** is needed to address these main barriers throughout the value chains.

Across technologies, we identify 5 main barriers:

- **Lack of human capital:** the shortage of skilled labour is a bottleneck present in all value chains. In some cases the deficit is more concentrated in academic training (engineers, physicists, chemists, etc.) while in others at vocational level (technicians, operators, installers, assemblers, etc.). In some sectors the lack of personnel is critical today (e.g. installing solar PV, offshore wind operators), and in others it is shaping up as a problem for the future (e.g. the need for more STEM professionals). The exceptional high speed in which the transition towards clean technologies needs to be implemented requires pro-active policy to mitigate the risk of labour quantity and quality becoming a (larger) barrier towards upscaling.
- **High supply chain dependency on China and protectionist support policies outside of the EU:** The EU and Spain are very dependent on China in most stages of the key technology value chains, particularly for raw materials and manufacturing. This, combined with generous, protectionist production support schemes in China and now in the US via the IRA, lead to a potential need for public support in Spain and the EU to maintain and increase manufacturing (and recycling and possibly mining) in the EU for key technologies. On EU-level, the recent Green Deal Industrial Plan (see textbox 9-2) is a first step towards a common European strategy to address this barrier and risk. More specifically, increased recycling could partially alleviate resource dependency, but currently there is a lack of economic and regulatory incentives for high quality recycling.
- **Current energy infrastructure lagging behind development of renewable energy production:** The transition to a decarbonized energy system also requires a transition of energy infrastructure. Most notably, massive public investments are needed in the electricity grid. Since grid expansion development normally is slower and lags behind expansion of solar and wind, timely planning and investments are necessary to keep up with renewable rollout.
- **Regulatory framework for electricity market not fully in line yet with renewable energy system.** Although on EU-level and in Spain great strides are made adapting electricity regulatory frameworks from a fossil to a renewable energy system, some improvements could be made. A lack of incentives for energy storage was mentioned by many interviewees as a major barrier. Next to this, some permitting procedures for renewable energy projects, such as the environmental impact assessment for solar and wind projects, are slow and delay renewables rollout. This can be the result from overcomplicated permitting procedures, but also from a lack of administrative capacity to process applications. Spain in 2022 already further simplified permitting for solar and wind.

- **Lack of RD&I support:** To increase competencies and competitive advantages for Spain in value chains, investing in Research, Development and Innovation are a key component towards developing the necessary capabilities in Spain. This is specifically relevant for the scale up phase between technology innovation and commercial viability (known as the “valley of death”). Our analysis shows this need is latent for electrolysers and for recycling processes of many of the technologies covered . RD&I is also highly related with potential increased manufacturing capacity in Spain and the EU; on one hand, RD&I could lead to breakthroughs and competitive advantage for European firms, while increased manufacturing could subsequently attract RD&I – especially in higher TRLs – and offer room for experimentation.

Most identified barriers are regulatory and are not directly due to a lack of (public) financing. Still, there is a need for financial support as part of a balanced policy mix. Even more so, a solid regulatory framework is needed to enable the effective use of public financing schemes. Hence, both are interlinked and should be approached in tandem. In the next chapter we will focus specifically on financial support schemes, but relevant insights related to regulatory barriers are also gathered at the end of this chapter. We define **regulatory barriers** as laws, regulations and non-financial policies that are not aligned and do no incentivize the required transition towards a new situation. **financial barriers** are defined as a lack of funding – private or public – for activities which are considered in the public interest.

Stable, simple and predictable policies are needed to keep attracting investments. according to stakeholders there have been several examples of quickly changing or poorly-designed policies in the past. Permitting procedures are also complicated for several activities and take place on several government levels – both national and regional -. An example of slow and/or complicated policies are the environmental permits necessary for solar farms, which are time-consuming and require a high workload from the authorities, although requirements have been simplified already last year.[316] RePowerEU also focuses on speeding up permitting processes.

Table 8-1 shows a more detailed summary of the barriers per value chain.

Table 8-1 Summary of severity of barriers, split into regulatory and financial barriers, for the 5 identified overarching barriers. More details can be found in the technology-specific chapters.

Overarching barrier	Lack of human capital	Supply chain dependency & global competition (materials, manufacturing & recycling)	Insufficient infrastructure development	Regulatory frameworks for electricity	Lack of RD&I support
Wind power	Shortage for construction, installation, O&M.	-Not able to compete on price with Chinese suppliers. -Recycling value chain not developed.	-Adapt Spanish port facilities.		
Solar PV	Shortage mainly for construction and installation	-Very high market concentration in China in all value chain steps, but less so for raw materials. -Undeveloped recycling value chain.	-Limited grid capacity hindering export of surplus.	-Lack of incentives for energy storage.	-Limited research on solar PV in Spain, especially in scale up phase.
Energy storage	-Shortage of skills for battery production	-High supply risks for e.g. several CRMs, anodes/cathodes. -Limited manufacturing capacity in Spain.	-Slow development of hydrogen transport pipelines	-Lack of incentives for energy storage.	-Lack of financing for scale-ups.

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[316] Reuters (2022). Spain's bulging solar pipeline heaps pressure on permitting

Electric mobility	-Shortage of skills for charging infrastructure		-EV infrastructure lagging behind EV expansion. -Faster rollout of chargers needed.	-Legal framework for charging stations lacking: need rules for e.g. bidirectional and smart charging and load management	
Hydrogen/ electrolysers	Shortage mainly for electrolyser maintenance and operation. -Limited knowledge in public administration on hydrogen.	-High supply risk for metals like titanium and platinum group metals. -Limited financing options.			-Limited support for upscaling of electrolyser/fuel cell innovation.
Heat pumps	Shortage of heat pump installers, system designers, and installers of newer technologies	-High supply risk for rare earth elements/permanent magnets used in electric motor -Low risk dependency on Asian component manufacturers			

While the focus of this report is on financial barriers and support schemes, interviews and the analysis shows the importance of solid regulation to drive the development of all value chains. Hence, below is a summary of the main identified regulatory barriers that were identified in the interviews. Note that this mainly reflects the view of interviewees and not necessarily reflects any recommendation from the authors.

- **General:** Interviewees stressed the need for stable policies upon which market actors can rely for project periods that can be more than 10 years. Next to this, in multiple sectors the competition from China is significant. In order to favour European industry, several ideas were proposed, but were not checked on quality: (i) local content requirements in tenders; (ii) purchasing decision criteria based on value rather than price; (iii) limits on carbon footprint; (v) requirement that there be subsidiaries in European territory, so as to guarantee adequate after-sales service; (vi) making agreements with countries producing raw materials. Since many of these measures are very protectionist, caution is advised and a coordinated EU-level approach – most logically through the EU Green Deal Industrial Plan (see textbox 9 in Ch9) – would make most sense. stakeholders in all value chains also mentioned that they experience highly bureaucratic and slow permitting processes (and subsidy acquisition processes).
- **Energy storage:** Amongst the interviewed stakeholders there was a unanimous call for a regulatory scheme that guarantees a revenue floor via capacity mechanisms, in particular for medium and large projects, and for measures to protect against Chinese competition in the battery value chain. Financial support programmes are asked for only to boost specific links or technologies that under current market conditions cannot be commercially scaled, but whose rapid development would represent a boost for the whole chain. This is the case for recycling and R&D activities, as well as for any link that requires a significant increase in scale in order to achieve a strong reduction in production costs, and consequently in prices.
- **Electric mobility: D**uring the interviews there was a call for reducing regulatory differences between different municipalities or Autonomous Regions, and the creation of one-stop shops to reduce the workload and timeframes for obtaining authorisation. Financial support programmes are asked for facilitating investments for the adaptation of production processes, incorporating

SMEs as central beneficiaries, together with reformulating consumer incentives so that the aid is granted at the time of purchase (instead of retroactively after 1-2 years).

- **Wind power:** Interviewees mentioned that wind companies are dealing with financial difficulties, due to rising inflation, high interest rates and component costs, as well as fierce competition with China. Spanish producers suggested to focus in tenders not only on price, but also on circularity, usability and quality, in which European producers score better than Chinese (also mentioned for solar PV).
- **Solar PV:** similarly to the energy storage value chain, there was unanimity among interviewees on the key role of policy predictability, and the need for changes in the policy/regulatory framework. One of the conclusions that emerged from the interviews is that Europe and Spain need to hurry, as the elements are now in place to boost the chain: there is considerable funding available, there is political will, there is awareness of the limits of globalisation and relying on East Asia, and there is investor interest in developing this industry. Several interviewees agreed that there is no need for massive resource allocation, and that most barriers are regulatory, such as the lack of a regulatory incentive for energy storage.
- **Hydrogen:** Industry stakeholders highlighted that there is a good RD&I environment for hydrogen in Spain. However, innovations often have difficulty with later stages of commercialization. For this “valley of death” between innovation and scale-up, public financial support can act as a crucial bridge. Developing project finance support for green hydrogen projects, and de-risking these investments, are also especially important for rapid growth in the sector to match Spain’s high ambitions. Moreover, stakeholders highlighted that many local or regional administrations lack the capacity to develop adequate support programmes for various projects in renewable hydrogen.
- **Heat pumps:** Experts indicate that on the demand side, heat pump financial aid can be simplified, streamlined, and better communicated, both at national and regional levels. The supply chain is still mainly dominated by large Asian manufacturers that own multiple patents on various components and will continue to set up shop in Spain. More vocational training is needed to support the heat pump industry, especially in training more heat pump installers (relying on the pool of HVAC personnel with certifications for refrigerant fluids), developing training programs for rapidly-growing technologies, setting up more training programmes for system designers and customizers.

9 Financial support analysis

In chapter 7 the main identified regulatory and financial barriers for key value chains were summarized. As has been highlighted, several of those barriers would need regulatory changes to be addressed. While some of the barriers identified can be resolved through additional public and/or private funding. Public support to overcome the financial barriers is justified if the objective of investments is in the wider public interest. The main public interest of developing these key technology value chains is clear: they're essential building blocks towards climate neutrality in Spain. Related to this, the economic benefits of supporting clean technologies can be large and can simultaneously reduce dependency on other global regions, which has recently become a more explicit objective with initiatives such as **REPowerEU** that sets out several measures to rapidly reduce dependence on Russian fossil fuels and advance the ecological transition, while increasing the resilience of the energy system at EU level, and the **EU Green Deal Industrial Plan** in response the US's Inflation Reduction Act (see textbox 9-2).

Hence, public financial support can be justified when private sector investments are insufficient to achieve these public goals. There are many reasons why private sector investments are insufficient. It could be that the public benefits are not sufficiently incorporated in the financial business case of project, there is not sufficient knowledge or information regarding a specific technology/project increasing the uncertainty risk, or a regulatory framework does not sufficiently reduce risks, thereby increasing the cost of capital and making projects financially unviable. Also, when overall confidence in the economy is low private investments can reduce, leading to a self-enforcing downward trend. To combat the economic uncertainty presented by the Covid-19 crisis, the **Recovery and Resilience Facility** was established.[317]

This chapter will identify suitable investment types for MITERD to overcome a lack of funding in key clean technology value chains that help address four of the five main barriers identified: **Support to upgrading human capital, support for manufacturing and recycling activities, support for infrastructure development and RD&I support**. Barriers related to the electricity regulatory framework are not discussed, since almost all solutions are of regulatory nature and financial. We use the following classification of financial support types, in line with the framework used by the Commission for the RRF.[318] Both non-repayable financial support (grants) as repayable financial support (financial instruments) are in scope. Textbox 9-1 presents definitions of main types of used financial instruments or schemes for renewable energy projects.

Textbox 9-1 Definition of types of financial schemes, in line with Ecorys (2023).

- **Grants:** non-repayable financial support. It should be noted that there are also forms of repayable grants, which are for example used in EU Cohesion Policy.
- **Loan:** An agreement which obliges the lender to make available to the borrower an agreed sum of money for an agreed time and under which the borrower is obliged to repay that amount within the agreed time.

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[317] Ecorys (2023). Study providing analytical support for the financial instruments and programmes to facilitate investment in the energy sector

[318] Ecorys (2023). Study providing analytical support for the financial instruments and programmes to facilitate investment in the energy sector

- **Guarantee:** A written commitment to assume responsibility for all or part of a third party's debt or obligation or for the successful performance by that third party of its obligations if an event occurs that triggers such guarantee, such as a loan default.
- **Equity:** Provision of capital to a firm, invested directly or indirectly in return for total or partial ownership of that firm and where the equity investor may assume some management control of the firm and may share the firm's profits.
- **Quasi-equity:** A type of financing that ranks between equity and debt, having a higher risk than senior debt and a lower risk than common equity. Quasi-equity investments can be structured as debt, typically unsecured and subordinated and in some cases, convertible into equity, or as preferred equity.
- **(Green) bonds:** Bonds are financial instruments that finance projects and provide investors with regular or fixed-income payments. A green bond is specifically earmarked to raise money for climate and environmental projects.
- **Risk sharing instrument:** A financial instrument which allows for the sharing of a defined risk between two or more entities, where appropriate, in exchange for an agreed remuneration.
- **Fund of funds:** A fund set up to contribute support from a programme or programmes to several financial instruments.
- **Project Finance Scheme:** long-term financing of large infrastructure and industrial projects based upon the projected cash flows of the project rather than the balance sheets of its sponsors. The debt or equity used to finance the project are paid back from the cash flow generated by the project.
- **Public-Private partnerships:** Cooperation structure between public and private stakeholders, with often a component aimed at attracting both private and public funding.

It is important to mention that energy projects, especially infrastructure projects, require large upfront investments compromising their commercial viability even under normal economic circumstances. Thus, public funding is essential for the development of these sectors. When the investment is income-generating or cost-saving, it is desirable to promote financial schemes with returns, in order to use public funds more effectively.

Responding to current urgency of the energy transition, Europe has implemented different measures to increase implementation speed. Most notably, the Green Deal Industrial Plan presents a new angle to European climate and energy policy, as it also adds an **industrial** policy component and aims to attract industrial activity to the EU. All details of the Industrial Plan are at the time of writing still developed, but a summary of the Strategy can be found in Textbox 9-2 below.

Textbox 9-2 EU Green Deal Industrial Plan

On 1st February 2023 The European Commission announced its EU Green Deal industrial Plan aimed at enhancing the competitiveness of the of Europe’s net-zero industry and ensuring open strategic autonomy.[319] The Plan is partially a response to the US Inflation Reduction Act (IRA) that announces $370 billion of spending and tax breaks aimed at combatting climate change. Most notably, the IRA includes significant tax breaks for clean technologies and includes a large ‘buy American’ component in which only products made in the US are eligible for tax breaks.

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[319] EC (2023). The Green Deal Industrial Plan

The new Industrial Plan aims to scale up European clean tech industry in a world of increasing global competition with mostly the US and China. This presents a notable shift in the EU's strategy. While current EU policy is relatively neutral about whom delivers the technologies necessary to reach net-zero, this EU Strategy – as well as the IRA – presents a (global) shift towards industrial policies that explicitly favour building up domestic production capacity.

The Plan – though still broad and lacking details - aims to support the net-zero industry through measures in 4 pillars. Several of the measures in the Strategy are not new; below we provide an overview focusing on new measures):

- **A predictable and simplified regulatory environment:** shorten permitting processes for key products through time limits and 'one-stop shops'; regulatory sandboxes; more European standards (notably on sustainability and circularity criteria); a Critical raw materials Act (not new).
- **Speed up access to finance:** the most important new measure is relaxing State Aid Rules temporarily until 2025 allowing MS to more easily support national industry via direct grants, tax breaks, subsidised interest rates or guarantees on new loans, etc. These provisions now count for all renewable technologies, there is no need for tenders for less mature technologies now and projects get extended deadlines. Also, MS are now able to match the aid of third countries to attract individual companies/production sites. Next to this, the Strategy starts the discussion on potential new EU-level funds supporting industry.
- **Enhancing skills:** this pillar presents skills as a priority for upcoming policy,but does not present any major concrete measures (yet), next to multiple smaller initiatives. The Commission promotes skills development mainly through establishing partnerships, including a European Pact for Skills, and specific partnerships for heat pumps and onshore renewable energy.
- **Trade and resilient supply chains:** The EU will continue to develop free trade agreements and other cooperation; a Critical Raw materials 'Club' in which resource-rich countries and consumers are connected.

To summarize, the Strategy proposes a few notable new measures but mainly shows that industrial policy and the importance of stable access to technologies and raw materials are becoming a main objective for the Commission. In terms of measures, the main discussion point will be the degree to which industry will be supported by national or EU-level funds.

The previous context on financial support schemes will work as introduction to the following analysis and recommendations on possible financial schemes that could be used to support the technology value chain barriers identified in prior sections of this report.

9.1 Support to upgrading human capital

Rationale for public funding support

The need for capacity building and upskilling of the existing workforce as well as the shortage of qualified personnel were highlighted as barriers for different technologies in different value chain segments, in particular:

	Wind power	Solar PV	Storage	Electric Mobility	Hydrogen	Heat pumps
Capacity building, training and professional qualification	Offshore	O&M Recycling	x	x	x	x

This entails the:

- need for capacity-building, training and professional qualification in the offshore wind energy sector.
- need for capacity building, training and professional qualification for construction and O&M for solar PV. The lack of know-how and experience to recycle/recover raw materials and components for solar PV.
- need for education and training programmes to increase the number of professionals and retain existing ones in the storage field, as highlighted by interviewees.
- need to upskill the labour force to match the increasing electrolyser capacity and to support the upgrade of human capital for hydrogen.
- shortage of qualified personnel for heat pump installations, as indicated in the interviews.

Public finance has a critical role to play in building human capital, in particular in the current context, as a response to the COVID crisis and as a central element in the energy transition[320]. Investments in the necessary skills development are expected to generate significant positive economic and social externalities.[321] However, these targeted investments should be matched with career guidance, knowledge exchange and awareness raising.[322] Governments, together with the private sector, should boost training programmes to meet the demands of the industries needed for the (energy) transition. [323] According to a study focused on 6 European countries (including Spain), subsidies and incentives targeting the private sector to stimulate the development of green skills are not prominent at the national level.[324] Alternatively, sector bodies and individual (large) companies, often form partnerships to develop green skills.[325]

At the **European level,** the main instrument to support upskilling and reskilling consists of **grants**, though some **debt instruments** are also provided (see annex II). The EU Skills Agenda[326] includes ambitious targets to upskill and reskill 120 million adults annually, and has earmarked funds to support training coming from the European Social Fund Plus (ESF+), the Just Transition Fund, and the Recovery & Resilience Facility. There are several EU funding instruments in place either accessible through the European Commission, financial intermediaries or through national authorities for upskilling and reskilling in view

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[320] World Bank. 2021. Investing in Human Capital for a Resilient Recovery : The Role of Public Finance.
[321] World Bank. 2021. Investing in Human Capital for a Resilient Recovery : The Role of Public Finance.
[322] Cedefop, 2021. The green employment and skills transformation: Insights from a European Green Deal skills forecast scenario.
[323] World Bank. 2021. Investing in Human Capital for a Resilient Recovery : The Role of Public Finance.
[324] Cedefop (2019). Skills for green jobs: 2018 update. European synthesis report
[325] Cedefop (2019). Skills for green jobs: 2018 update. European synthesis report
[326] https://ec.europa.eu/social/main.jsp?catId=1223

of the transition.[327] Grants are available for innovative approaches in the field of upskilling and reskilling, infrastructure and equipment for training, for targeted audiences (such as workers at risk of losing their job or affected by the transition) or - specifically – to support the green and digital transition and resilience (i.e. by focusing on assessing the needs for green skills). In the case of debt finance, support is available for both the demand and supply side of skills: i.e. students and learners, SMEs and mid-caps as well as providers of training.

In **Spain**, for example, MITERD's Empleaverde Program[328], co-financed by the European Social Fund, aimed to promote and improve employment, entrepreneurship and the environment. In previous calls, it supported programmes targeting capacity building for wind and solar PV. IDAE also has some initiatives that support training in key technologies for energy projects. For instance, the fourth call supporting innovative value chain of renewable H_2 (under the framework of the RRP) includes financing for training activities, covering a wide range of costs (personnel, equipment, assessment…) needed for training actions regarding the hydrogen value chain. Annex II provides examples of schemes that support human capital upgrading tackling the barriers listed above.

Recommendations on possible actions

Spain should provide specific instruments that can motivate **different stakeholders to take action in improving the supply and demand for the necessary green skills.** Several of the identified barriers go beyond the lack of awareness and point to more substantial issues for which companies, labour market organisations, and skills development providers need to invest to find a solution. Providing (financial) incentives can stimulate developments in this area, particularly focusing on:

- **Subsidies to companies and sectoral organisations to finance tailored trainings and certifications** for employees.
- **Grants to skills development providers (VET providers and employment services),** to develop/adjust and promote relevant training courses and certifications on specific technical skills that are in need on the labour market (i.e. offshore wind, hydrogen & PV).
- **Grants to support pilot cooperative projects** that allows skills development providers and sectoral representatives or individual companies to work on concrete common projects. Through such a project-based approach, representatives of relevant economic sectors can be offered concrete means to interact with participating education provider(s) and strengthen the joint approach to the necessary skills.

More broadly, grants could also be used to support awareness raising programmes targeting young people (e.g. at school or high school level, regarding green skills among students). Such support should ensure policy coherence between labour, educational, energy and environmental policies as well as coordination among ministries and social partners.

9.2 RD&I support

Rationale for public funding support

Boosting and upscaling the renewable energy industry in Spain will need to tackle different barriers along the complete value chain. Research, Development and Innovation support is crucial incorporating new technologies in a specific sector; including new ways of producing, using or recycling a specific existing

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[327] https://ec.europa.eu/social/main.jsp?catId=1530&langId=en

[328] https://www.empleaverde.es/

technology; producing new components or materials; pilot the already developed technologies or components; or moving an existing industry to produce or include new elements needed to close the gap.

RD&I processes normally require a long period of time, as well as intensive human and monetary resources. Thus public incentives could be needed to support industry and academia to work together and rapidly move from research and development to applied innovation among other traditional support.

The need of **RD&I** and specially in later TRL stages, was identified in all technologies analysed and in particular in the following areas:

	Wind power	Solar PV	Storage	Hydrogen	Heat pumps
Local component manufacturing		x	x		
Cost reduction & efficiency		x			
Circular economy - ecodesign	x	x	x		
Circular economy - end-of-life/ recycling	x	x	x	x	x
Testing and demonstration	x				

The Intensity of public aid and the type of financial instruments are normally defined according to the RD&I advancement and the risk level. Thus, public aid in the form of grants will be mostly needed in early stages of research while stages closer to market viability are more willing to include private sector participation and diverse and more sophisticated financial mechanisms including blending schemes[329]. The size of the company is also an element to consider regarding the intensity of the grant support.[330]

According to the barriers listed in previous chapters and after analysing some existing public funding mechanisms for the technologies, the following could be possible financial instruments applying for the specifics needs identified. It is important to notice that public resources should be offered as complementary to market resources when funding is scarce and according to the country strategy and market needs.

RD&I grants financing could be encountered either financing up to 100% of the project or less percentage when commercial stages advance. For example, the **Faraday Battery Challenge initiative of UK Research and Innovation** has founded **research projects** through **grants solutions** for extending battery life, improve designs and performance of batteries with non-so expensive prototypes, recycling EV Lithium-ion batteries, battery science, next generation electrode manufacturing, among other projects. And it offers grants for around 70% to 80% of **innovation projects** for developing technical and commercial stages of technologies, feasibility studies, accelerating technologies, develop the next generation material.

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[329] OECD (2012), OECD Science, Technology and Industry Outlook 2012, OECD Publishing, Paris, https://doi.org/10.1787/sti_outlook-2012-en. Phase2-SANS-TOC.book (oecd.org)

[330] Some examples of the intensity of support according to the size of the company may be founded on: Smart: innovation funding guidance – UKRI. https://www.ukri.org/councils/innovate-uk/guidance-for-applicants/guidance-for-specific-funds/smart-innovation-funding-guidance/ and Research, Development and Innovation (RD&I) Fund - Enterprise Ireland (enterprise-ireland.com)

Textbox 9-3 Innovate UK support for Battery Research and Innovation[331]

The **Faraday Battery Challenge** is run by UK Research and Innovation on behalf of the UK government. With an investment of £330 million between 2017 and 2022, the challenge aims to support development of world-class science, technology and manufacturing scale-up capability for batteries in the UK. The challenge is focused on developing cost-effective, high-performance, durable, safe and recyclable batteries to capture a growing market. Initially addressing eight present-day limitations of automotive battery technology, the challenge allows the UK to realise its commitment to move to full electrification and zero-emissions vehicles. The challenge is also looking to address other sectors including aerospace and rail. It comprises three stages to market: research, innovation and scale-up.

Textbox 9-4 Innovation Fund Grant financing[332]

The Innovation Fund will support up to 60% of the additional capital and operational costs of large-scale projects and up to 60% of the capital costs of small-scale projects. The grants will be disbursed in a flexible way based on project financing needs, taking into account the milestones achieved during the project lifetime. Up to 40% of the grants can be given based on pre-defined milestones before the whole project is fully up and running.

Grants could also be refundable, linking reimbursement to project progress or commercial return. An example of innovation **grants** is the ADEME **Programme d'Investissements d'Avenir or Investments for Future**[333] support fostering innovative projects promoted by start-ups and SME´s, the acceleration of innovative ecosystems for transport and mobility promoting the partnership between a research institute and a private partner, and developing demonstration projects for energy transition. ADEME support in this case offers financing mixing **refundable and nonrefundable grants**_(2/3 and 1/3 respectively). The refundable mechanism is used for investing in R&D and innovative projects testing in real conditions. The return mechanism is correlated to the project success, specially for large companies, following this methodology:

- No commercial deployment: reimbursement according to progress.
- Commercial deployment: reimbursement of for example 50% according to project progress or first EURO turnover.
- Reimbursement of other 50 % if surpassing the commercial success target form example

In addition to grant solutions, there are some possible **financial instruments** that could be used with soft conditions to support innovation on energy. **Equity investment** tools could work as direct investment from the government, that for instance, could play the role of market investor – for commercial first-of-a-kind innovative industrial (see ADEME). The government could also invest trough VC Funds where public resources work as a signalling to other venture or angel investor bringing smart capital to the project. The Lithuanian National Financial Development Institution **INVEGA**[334] has developed three financial instruments dedicated to RDI trough a VC Fund scheme. Other option for smart capital complemented with technical expertise could be the **Dutch Innovation broker subsidy**[335] for start-ups serving as an investment banking specialized service for these kind of companies.

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[331] UK Research and Innovation (2021). Faraday Battery Challenge: funded projects to date https://www.ukri.org/wp-content/uploads/2021/10/UKRI-051021-FaradayBatteryChallengeFundedProjectsBookletSept2021.pdf

[332] Innovation Fund. https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/programmes/innovfund

[333] ADEME (2019). PIA 3 https://climate.ec.europa.eu/system/files/2019-04/20190328_pia3_en.pdf

[334] EIB (2020). Stocktaking study on financial instruments by sector https://www.fi-compass.eu/sites/default/files/publications/Stocktaking%20study%20on%20financial%20instruments%20by%20sector%20-%20The%20Lithuanian%20RDI-specific%20equity%20instruments.pdf

[335] Energy Innovation NL (2023). Innovation Brokers Subsidy https://topsectorenergie.nl/en/financing-desk/innovation-brokers-subsidy

On the side of **debt instruments**, soft **loans** could enable the company to finance part of the project costs when banks and other investors will not invest in for high risk though promising project. An example of this may be the **UK Innovation loan**[336] that provides affordable, flexible and patient capital to SME´s on the later stage of research and development projects with a clear route to commercialization and business growth through innovation. Loan conditions are normally designed depending on the needs of the project. Finally, **credit guarantees could be used** to increase the collateral to borrow to the private sector when the risk is high.

In **Spain**, IDAE and MITERD have launched different calls related to RD&I in areas such as energy storage hydrogen or wind power:

- "Proyectos innovadores de I+D de almacenamiento energético"[337]. This call, part of the PERTE ERHA, is dedicated to support RD&I projects of energy storage in order to develop technology, knowledge and industrial capacities as well as new business models to reinforce Spain's position in this field.
- "Programas de ayuda a la cadena de valor innovadora del hidrógeno renovable"[338], dedicated to support pioneering and unique renewable hydrogen projects, with four different calls targeting the hydrogen value chain. Supports RD&I capacity strengthening and component testing.
- "Programa RENMARINAS DEMOS"[339]. This program includes four different subprograms, covering technology demonstrators, test platforms and joint projects for marine renewables.

Most of the initiatives identified to support RD&I projects are grant-based. The different calls analysed establish limits of aid intensity for each action and/or beneficiary. Normally grants come to complement private finance either from the own company or project of from the financial system. Public support schemes based on alternative financial instruments (such as loans or equity) are less frequent in this type of projects. Some examples of initiatives to support R&D&I focused on the identified barriers can be found in Annex II.

Recommendations on possible actions

Financial support to RD&I investments to unlock existing barriers in Spain could focus on scaling up technologies that under current market conditions cannot be commercially scaled or gaining in cost reduction due to technology innovation; it could also focus on supporting a leading industry to maintain its role and gain competitive advantage for the future. Recycling and eco-design industry needs to gain traction in the country, thus financing support on recycling technologies innovation is also relevant to build the competitiveness of the industry in the near future and to comply with the EU regulation in terms of wind turbines, solar panels and batteries recycling.

According to the needs raised by the industry during the interviews the following **key areas of possible** intervention and support in RD&I are identified:

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[336] UK Research and Innovation (2022). Innovation loans https://www.ukri.org/councils/innovate-uk/guidance-for-applicants/guidance-for-specific-funds/innovation-loans/

[337] IDAE (2022). Proyectos innovadores de I+D de almacenamiento energético https://www.idae.es/ayudas-y-financiacion/primera-convocatoria-para-proyectos-de-id-de-almacenamiento-energetico-dentro

[338] IDAE (2022). Cadena de valor innovadora del hidrógeno renovable https://www.idae.es/ayudas-y-financiacion/programas-de-ayuda-la-cadena-de-valor-innovadora-del-hidrogeno-renovable-en

[339] IDAE (2023). Proyectos piloto y plataformas de ensayo e infraestructuras portuarias para renovables marinas https://www.idae.es/ayudas-y-financiacion/programa-renmarinas-demos

- **Support the financing of new and existing RD&I initiatives**, either by extending the scope of the aid lines previously launched or by earmarking new specific aid lines for:
    - Developing technologies and strategies for reusing, recycling, or repurposing in the different technologies
    - Eco-design for future recycling and repurposing
    - Promoting local production of components, creation, or adaptation of existing manufacturing facilities to deal with specific components.
    - Reducing cost of producing components and increasing efficiencies in factories
    - Developing lighter and more efficient materials
    - Digitalisation processes and logistic optimization along the value chains

  For instance, the "Proyectos innovadores de I+D de almacenamiento energético" call could include or be complemented by an eco-design or recycling option on the possible uses of grants. It could also mix the form of additional contingency financial options when commercial return is expected (like refundable grants).
- **Support industry and academia to work together and rapidly move from research and development to applied innovation**. Funding innovation and market scaling stages, supporting collaboration among research institutes and industry, and funding RD&I trough open innovation schemes withing the industry could be useful for technologies needing support on scaling-up innovation like storage value chain.
- **Foster innovation for adapting existing manufacturing facilities to deal with specific components or face demand changes**. According to the interviews there is industrial capacity in Spain that needs to be reoriented or reinforced to produce new components or upgrade the existing ones. There is also a need for more flexible factories, with the capacity to adapt to demand fluctuations and rapidly respond to market needs. Existing calls could be strengthened including innovation for flexible facilities support for hydrogen, wind power or storage for example, or the circular economy calls when the need is in the recycling stage.
- **Future R&D support should continue focusing in scaling up technologies and linking research with industry innovation and demonstration** to maintain the leading role of Spain in some technologies and gain momentum or a medium-term strategic positioning in others. Even though the industry highlighted the strengths of the Spanish RD&I ecosystem during the interviews, it is important to increase support in strategic areas to meet the decarbonization targets. This is the case of the Wind Power industry that needs important RD&I investment to maintain its leading role in the global context or the Hydrogen that needs to gain scale production and uses to improve profitability.

9.3 Support for manufacturing and recycling activities

Rationale for public funding support

Unlocking some parts of the Spanish renewable energy value chains studied, would require an effort at **strengthening local business and industries** allowing local production to keep pace with the speed at which some markets/technologies are growing and others are expected to grow. In addition, it is important that existing and planning **technological innovations** with the possibility to give Spain a more competitive advantage can **be scaled up** and gain traction in terms of **production and massification**.

For this purpose, the analysis in this chapter will focus on the barriers in terms of strengthening, boosting, or scaling up the **manufacture** of materials, components, and technologies, as well as creating/strengthening the **recycling** industry, repairing or extending the lifecycle of the technologies, components and materials of these technologies.

The needs for manufacturing and recycling capacities support were identified in all the technologies analysed as a measure to overcome some existing barriers, in particular:

	Wind power	Solar PV	Storage	Hydrogen	Heat pumps
Local component manufacturing		x	x		x
Cost reduction & efficiency		x			
Circular economy - end-of-life/ recycling/life extension	x	x	x	x	x

During the interviews it was noted that important support appears to be needed in strengthening manufacturing or recycling capacity on an **industrial** level connecting to the RD&I needs on scaling up proven innovative technologies. Investment needs for developing or scaling up manufacturing facilities are often associated with their investment costs, also referred to as the factory's CAPEX . Textbox 9-5 below provides an overview of recent estimates of CAPEX needs for European manufacturing facilities of selected energy technologies, namely wind power, solar PV, heat pumps, battery cells and electrolysers.

Textbox 9-5 Estimates of CAPEX needs for European manufacturing facilities of clean energy technologies.

The investment costs for building new manufacturing plants, or expanding existing manufacturing facilities (Factory CAPEX) for the main components and technological assembly of the clean energy technologies are highly dependent on project specific features. Therefore, Factory CAPEX can vary greatly depending on the new projects announced, their location and specific product features.

On 23 March, 2023 the European Commission published a **Standard Working Document on** investment needs assessment on requirements and available funds for key net-zero technologies until 2030. [340]The document included Factory CAPEX for five of the clean energy technologies covered in this study. These estimates were based on literature review (such as BNEF or other sources), and exclude investments up-stream and down-stream supply chains (e.g. raw and processed inputs) as well as expenditures related to the operation of the manufacturing facilities (OPEX).

Table 9-1 Factory CAPEX of selected clean energy technologies. Source: European Commission (2023).[341]

Technology	Factory CAPEX (M€/unit*/year)	Capacity unit*
Wind	260	GW/year
Solar PV	340	GWAC/year
Heat pump	333	GW/year
Battery cell	144	GWh/year
Electrolysers	60	GW of electricity/year

In the case of batteries, the costs for building new battery gigafactories in the EU are estimated at around EUR 100 million/ GWh, considering that investment costs for cell producers largely include buildings and the

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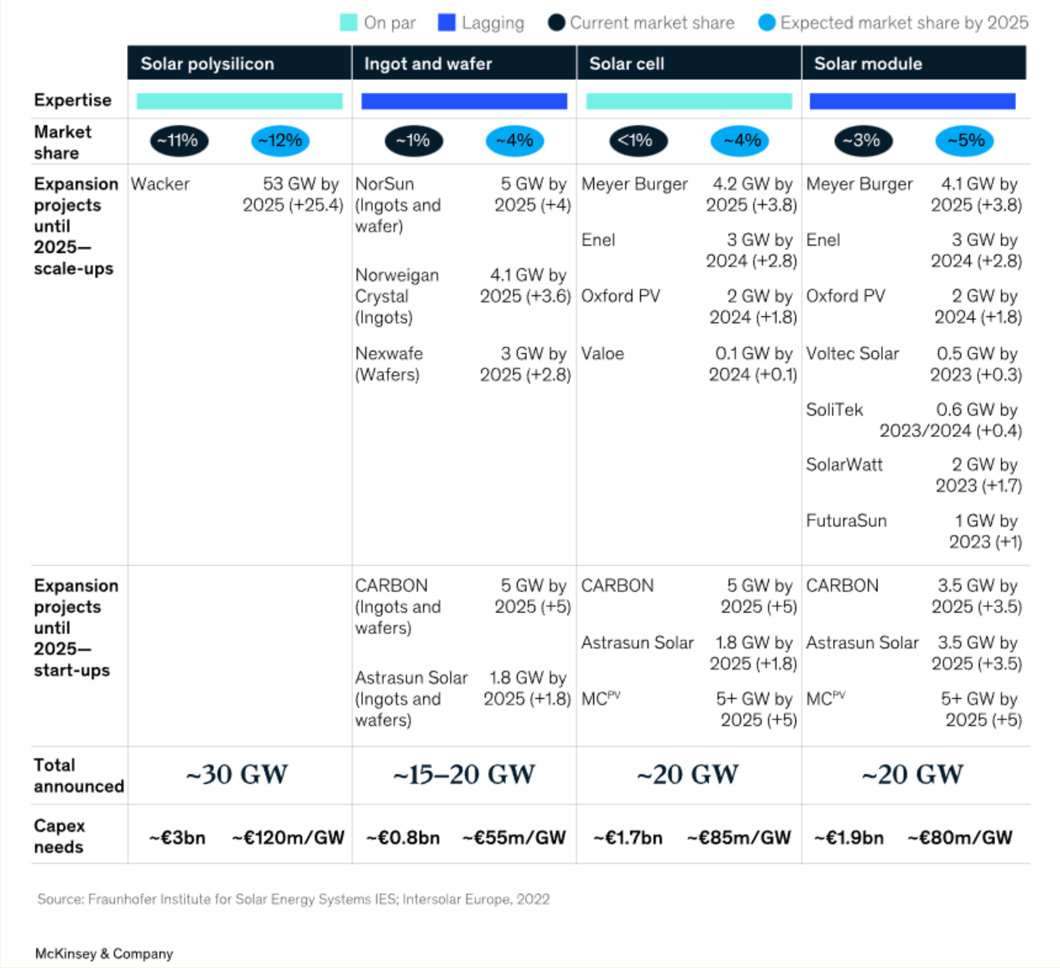
[340] SWD(2023) 68 final -Staff Working Document - Investment needs assessment and funding availabilities to strengthen EU's Net-Zero technology manufacturing capacity.

[341] SWD(2023) 68 final -Staff Working Document - Investment needs assessment and funding availabilities to strengthen EU's Net-Zero technology manufacturing capacity.

required machinery to produce cells. These estimates can increase to EUR 150 million / GWh when cathodes and anodes production are added.[342]

In the case of Solar PV, other sources provide **estimates** available **of** Factory CAPEX needs disaggregating by the specific for different segments of the Solar PV production **(see Figure 9-1 below.** These estimates were based on the few announcement of expansion plans for European Solar PV manufacturing plants, resulting in around EUR 120 m/GW in the case of solar polysilicon plants, EUR 55 million /GW for ingot and wafer plants, EUR 85 million / GW for solar cell plants, and EUR 80 million /GW for solar modules. [343]

Figure 9-1 Announcement of expansion plans for European Solar PV manufacturing plants, and estimates of associated capex needs . Source: McKinsey (2022).[344]



🟩 On par 🟦 Lagging ● Current market share ● Expected market share by 2025

	Solar polysilicon		Ingot and wafer		Solar cell		Solar module	
Expertise	🟩		🟦		🟩		🟦	
Market share	~11%	~12%	~1%	~4%	<1%	~4%	~3%	~5%
Expansion projects until 2025—scale-ups	Wacker	53 GW by 2025 (+25.4)	NorSun (Ingots and wafer)	5 GW by 2025 (+4)	Meyer Burger	4.2 GW by 2025 (+3.8)	Meyer Burger	4.1 GW by 2025 (+3.8)
					Enel	3 GW by 2024 (+2.8)	Enel	3 GW by 2024 (+2.8)
			Norweigan Crystal (Ingots)	4.1 GW by 2025 (+3.6)	Oxford PV	2 GW by 2024 (+1.8)	Oxford PV	2 GW by 2024 (+1.8)
			Nexwafe (Wafers)	3 GW by 2025 (+2.8)	Valoe	0.1 GW by 2024 (+0.1)	Voltec Solar	0.5 GW by 2023 (+0.3)
							SoliTek	0.6 GW by 2023/2024 (+0.4)
							SolarWatt	2 GW by 2023 (+1.7)
							FuturaSun	1 GW by 2023 (+1)
Expansion projects until 2025—start-ups			CARBON (Ingots and wafers)	5 GW by 2025 (+5)	CARBON	5 GW by 2025 (+5)	CARBON	3.5 GW by 2025 (+3.5)
					Astrasun Solar	1.8 GW by 2025 (+1.8)	Astrasun Solar	3.5 GW by 2025 (+3.5)
			Astrasun Solar (Ingots and wafers)	1.8 GW by 2025 (+1.8)	MC^{PV}	5+ GW by 2025 (+5)	MC^{PV}	5+ GW by 2025 (+5)
Total announced	~30 GW		~15–20 GW		~20 GW		~20 GW	
Capex needs	~€3bn	~€120m/GW	~€0.8bn	~€55m/GW	~€1.7bn	~€85m/GW	~€1.9bn	~€80m/GW

Source: Fraunhofer Institute for Solar Energy Systems IES; Intersolar Europe, 2022

McKinsey & Company

Additional to the technical barriers, it was identified during some interviews, that in the case of hydrogen projects, financing is not flowing at the scale needed to achieve industrial decarbonisation and green transition. One of the main reasons behind this lack of funding is that there is still low profitability in the Hydrogen projects and project finance structures are not yet applied by the financial sector. This is due to the low number of previous initiatives financed to endorse the implementation of these instruments

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[342] SWD(2023) 68 final -Staff Working Document - Investment needs assessment and funding availabilities to strengthen EU's Net-Zero technology manufacturing capacity. Original source: BNEF (2022) "Localizing Clean Energy Supply Chains Comes at a Cost".

[343] McKinsey (2022). Building a competitive solar-PV supply chain in Europe.

[344] Ibid.

in the field of green hydrogen. This impacts on the lack of sufficient knowledge and high risk perceived by financial institutions.

The main factors for market failures to be covered for financial schemes could be related with limited bankability of projects, long payback periods and low rate of return of the investments (for example when market is not yet well developed, such as hydrogen production and recycling capacity in general, or the cost of producing is still too high – such as for batteries), high risk of investment for instance, large projects as wind offshore farms with some market or regulation uncertainty, difficulties to quantify the financial benefit of the projects; insufficient collateral and low credit scores, among other failures. See **Czechia environmental risk loan instrument**[345] developed by the EIB.

It is also important to consider that financial needs of companies are also different depending on the maturity of the company life cycle. For example: **Start-ups** typically have large financing needs not finding those on the traditional financial market due to its high risk, no track record and little collateral, so seed money from investors such family, business angels and early-stage venture capital could be their main option. Public support schemes for this stage could take the form of mainly **grants**, but also **direct equity investment** or **quasi equity** such as convertible loans as the ones offered by the EIC Accelerator Program could be an option for these companies[346].

From the government side, structuring **seed or venture capital funds** or even explore a **Fund of Funds schemes**, willing to finance **equity or quasi equity** or be an investor in some other funds could be a way to promote other investors to support the scaling up of these companies.

Textbox 9-6 The EIC Accelerator[347]

The **EIC Accelerator** supports individual small and medium enterprises (SMEs), in particular startups and spinout companies to develop and scaleup game-changing innovations. In some cases, small mid-caps (up to 500 employees) are supported. It offers **grant funding** (non-dilutive) for innovation development costs, including demonstration of the technology in the relevant environment, prototyping and system level demonstration, R&D and testing required to meet regulatory and standardisation requirements, intellectual property management, and marketing approval (e.g. at least TRL 5/6 to 8), and **investments** (direct equity investments or quasi-equity such as convertible loans) for scale up and other relevant costs.

Growth phase firms have more track record to prove their business yet incorporate high risk on the growing phase. Late-stage **venture capital** could be relevant for companies with high growth potential and innovative products. **Bank loans** and raising some capital, through **private equity** markets, could be an option too and going to a **public offering** at a later stage is a possibility. Nonetheless, when a big push is needed, public resources could come as a way to **reduce collateral for banking debt**, incentivize first high-risk investment to crowd in private equity either in the form of grants or concessional debt, contingency debt or equity link to commercial returns.

Mature phase firms and large firms have smaller external financing needs which are normally covered by bank loans and bond financing, as well as equity. Financial tools in this case should be directed to

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[345] EIB (2020). Stocktaking study on financial instruments by sector https://www.fi-compass.eu/sites/default/files/publications/Stocktaking%20study%20on%20financial%20instruments%20by%20sector%20-%20Environmental%20risk%20loan%20in%20Czechia.pdf

[346] See EASME | Executive Agency for SMEs (archive-it.org) for more examples of support for Start-ups and SMES

[347] https://eic.ec.europa.eu/eic-funding-opportunities/eic-accelerator-0_en#eic-work-programme-2023

reorienting investments of the firm to a new business or technology needed. For example, moving gigafactories manufacturing automotive batteries to stationary batteries or dynamizing the recycling of materials or component industry. Other value chains will need investments in **recycling facilities** to, for example, address the issues of projects decommissioning or resource scarcity. Public investments and public-private partnerships can also address some of the needed investments, for example in recycling infrastructure.

Textbox 9-7 illustrates the support of the US Government, in the form of loans to a private company that wants to invest in recycling of end-of-live batteries to address the components segment of the value chain of this technology.

Textbox 9-7 Redwood Materials receives conditional loan from the Department of Energy of the USA[348]

The Loan Program Office of the Department of Energy (DOE) of the United States Government has offered a conditional loan to Redwood Materials for building a pioneering facility for recycling and production of battery components to support the domestic EV supply chain. The facility will be built in Nevada, and it is expected to create 3,400 construction jobs. This support from DOE contributes to establishing a domestic supply chain for batteries in the US, as Redwood can recover more than 95% of the critical battery element of and end-of-life battery, including lithium, nickel, cobalt, manganese and copper, and use them to manufacture anode and cathode components for the US battery cell manufacturers.

In **Spain**, IDAE supports repowering and recycling through different initiatives. One of the most recent ones is the **Programas de Repotenciación Circular**[349] call (as part of the PERTE ERHA and Circular Economy PERTE), divided in three different programmes:

- Program 1: Repowering of wind power facilities.
- Program 2: Technological and environmental renewal of hydroelectric power plants up to 10 MW.
- Program 3: Innovative facilities for the recycling of wind turbine blades.

Additionally, the H2 Cadena de Valor program was launched to support the value chain of hydrogen. In particular, the first call aims to finance equipment manufacturing centres related to renewable hydrogen (in particular, manufacturing facilities and equipment for other units, components, and systems).

MITERD has a **call as well in the frame of the Circular Economy PERTE**[350] to promote sustainability and circularity of industrial and business processes to improve competitiveness and innovation in the framework of a circular economy. This call is MITERD’s response to the increasing demand of sectors and enterprises of this kind of initiatives. More than 1200 proposals were sent during the expression of interest stage.

Recommendations on possible actions

Manufacturing and recycling capacity financing is related with business/industrial strengthening or competitiveness support programs where the role of the public sector could act as a catalyser of a specific **national strategic sector** where high risk is still perceived by the financial sector or there is low capacity to move forward at the pace the country needs. In that context public support schemes could be design aligning **the industrial and green transition ministries** to stimulate and facilitate the development of

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[348] https://www.energy.gov/lpo/articles/lpo-offers-conditional-commitment-redwood-materials-produce-critical-electric-vehicle; https://www.redwoodmaterials.com/news/redwood-department-of-energy-loan/

[349] IDAE (2023). Programas “Repotenciación Circular” https://www.idae.es/ayudas-y-financiacion/programas-de-repotenciacion-circular

[350] MITERD (2022). https://www.miteco.gob.es/en/prensa/ultimas-noticias/el-miteco-convoca-ayudas-por-valor-de-192-millones-de-euros-para-impulsar-la-econom%C3%ADa-circular-en-las-empresas/tcm:38-549081

competitive enterprises and to crowd in private sector capital. In this context blended finance structures mixing public and private resources rebalance investment risk-return or work as a signalling tool to crowd in private sector when large amounts of resources are needed.

Considering the current situation regarding manufacturing and recycling, strategies to mobilize finance could be related with some of the following aspects:

- **Understand the private sector and projects times and realities** and adapt the instruments to these rational to make project feasible thanks to the public support. This includes diminishing times and requisites of public procedures and designing instruments considering the projects maturity timing.
- **Support proven innovations speed-up in reaching the market and gaining commercial volumes** to secure profitability. This strategy could be of relevance when national manufacturing of components is needed to reduce the dependency of external supply and gain participation in higher value added in the chain.
- **Finance cost reduction** or **the first high-risk investment** with soft instruments either in capital or debt to solve the initial stage low profitability dilemma or increase profitability in highly strategic industries. This could be crucial when supporting the component manufacturing supply for the high-speed growth of energy projects for next years, for example for storage components and hydrogen manufacturing projects or undeveloped recycling structures in any value chain.
- **Promote the participation of SMEs in other financial structures like the green bonds** market to move more capital on interesting conditions when public grants cannot reach some companies or sectors.
  When SMEs are the ones accessing the public market, their stock value is normally punished so helping strategic SMEs with guaranties to decrease the risk perception and upgrade a notch on their qualification could improve the financial conditions the market offers to SMEs.
- **Support knowledge of hydrogen projects on financial systems** to promote the availability of resources, specially incentivize their bets on project finance structures, so privilege the project over the company balance that could sometimes not be as strong as needed to support this kind of projects in an early-stage sector.
- **Support the adaptation of existing manufacturing facilities to deal** with specific components. There is some industrial installed capacity in Spain that needs to be reoriented or reinforce to produce new components or upgrade the existing ones. This could be supported strengthening existing calls including reinforcing manufacturing installations to gain the needed capacity or be flexible enough to move and reorient to new opportunities or according to supply and demand changes. This could work for instance for stationary batteries, wind power components and electrolysers production. The support on capex investment here could complement the innovation efforts.

It is important to mention that the introduction of the EU Green Deal Industrial Plan announced in February 2023 should benefit the reorientation or design of public support to scale up the clean tech industry to face global competition. Of special relevance are the elements relaxing State Aid Rules until 2025 allowing Member states to support national industry more easily via tax advantages, subsidies, etc.[351]

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[351] Temporary Crisis and Transition Framework (europa.eu)

In line with the Green Deal Industrial Plan and the amendments to the General Block Exemption[352], in March 2023, the European Commission adopted the Temporary Crisis and Transition Framework to foster support measures in sectors which are key for the transition to a net-zero economy.

Textbox 9-8 Temporary Crisis and Transition Framework adopted in March 2023.

A new Temporary Crisis and Transition Framework[353] was adopted on 9 March, 2023 introducing new measures to further accelerate investments in key sectors for the transition towards a net-zero economy, enabling **investment support for the manufacturing of strategic equipment**, namely batteries, solar panels, wind turbines, heat-pumps, electrolysers and carbon capture usage and storage **as well as for production of key components and for production and recycling of related critical raw materials.**

The following initiatives are included as part of the TCTF amendment:

- It prolongs the possibility for Member States to further support measures needed for the transition. Especially schemes for accelerating the rollout of RE and energy storage, and the decarbonization of industrial production. Schemes can now run up to 31 Dec. 2025.
- **It amends the scope of such measures to make support schemes even easier to design and become more effective by: i) simplifying grants conditions for some projects, expanding support possibilities, lifting need for competitive bidding process for some projects, ii) expanding the possibilities of support for the deployment of all types of renewable energy sources, iii) expanding the possibilities of support for the decarbonisation of industrial processes switching to hydrogen-derived fuels, and iv) providing for higher aid ceilings and simplified aid calculations.**

9.4 Support for infrastructure development

Rationale for public funding support

Building of new infrastructure or reinforcement of the existing one has been recognized as a solution to barriers in most value chains analysed in this report. For instance, the wide-spread and desired increase of electric mobility requires the development of charging infrastructure, both **charging stations and grid reinforcement**.[354] Grid reinforcement will also be needed for accommodating the energy produced from renewable sources, such as wind or solar. Similarly, the logistics segment of the value chain in the offshore wind power technology will need **new infrastructure or potentially adaptation of the existing facilities in the ports**, for testing, construction, assembly and maintenance of offshore wind farms installations.

	Wind power	Solar PV	Storage	E-mobility	Hydrogen	Heat pumps
Charging stations and charging networks			x	x		
Grid reinforcement and interconnections	x	x	x	x		x
Adaptation of ports	x					

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[352] Endorsed by the European Commission on March 2023. Regulations (europa.eu)

[353] Temporary Crisis and Transition Framework (europa.eu)

[354] It is estimated that the cost of reinforcing the grid to support a single public direct-current fast-charging station with four chargers of 150 kW each would cost over 140,000 EUR (https://www.mckinsey.com/industries/public-and-social-sector/our-insights/building-the-electric-vehicle-charging-infrastructure-america-needs).

While they enable a smooth value chain for clean technologies, all these infrastructural needs have a value chain of their own and require raw materials, such as copper and aluminium for which the demand is expected to soar in the next decades. Moreover, an infrastructure project can stretch to over a decade from initial idea to finalization, most of the time being taken up by planning and permitting, which, however, can entail considerable investment. Indeed, the major characteristic of infrastructure projects is that they are highly capital intensive and require large upfront fixed cost. Indeed, a study by McKinsey[355] suggests that the net-zero scenario in Spain would need a total of EUR 2.5 trillion investments in green technology and processes,[356] from now until 2050. This translates into an average of EUR 85 billion per year, amounting to 6.2% of Spain's GDP.

Hence, the returns to such investments are usually recouped during long periods of time after they are realized, through the operating life of the completed infrastructure project. Moreover, the type of infrastructures required for the transition to clean technologies and the purpose for which they are built are unprecedented and, therefore, face risks that are difficult to anticipate. They are most often related to pioneering activities for which established business models do not yet exist. Moreover, this type of infrastructure and its operation is often regulated, and it is of a rather public interest. This makes it less attractive for pure private investment, giving rise to market failure. Therefore, infrastructure projects have been typically executed with government funding by public authorities or companies that are under the state control.[357] However, even when these types of investments are in the hand of the private sector, financial support from the state is needed to bring them to reality. This support comes most often in the form of grants. For example, at the EU level, the Recovery and Resilience Facility offers grants that may cover up to 100% of projects costs for energy and transportation infrastructure projects. [358] Yet, private finance through debt, guarantees for debt, equity or through public-private partnership models can also be channelled to infrastructure projects.

At the **EU level,** through the current 2021-2027 Multi-annual Financial Framework and the NextGenerationEU, the EC has also put forth a number of financial instruments, ranging from grants (e.g. through the Connecting Europe Facility - CEF) to loans, guarantees and even equity, that can provide the financial resources for the infrastructure needed to address the aforementioned barriers. A few examples are provided in Annex II.

At the level of MSs, national governments also promote investments in infrastructure through various financial products:

- The German Federal Government, through its Ministry of Transport and Digital Infrastructure, together with the Credit Institute for Reconstruction (de: Kreditanstalt für Wiederaufbau - KfW) have launched a **grant program**[359] at the end of 2020 to promote the **installation of charging stations for electric cars** in areas of residential buildings not accessible to the general public. Through this program, the investors receive EUR 900 for each charging station installed.
- More recently (end of 2022), the German Federal Government has also approved a plan of EUR 6.3 billion to ramp up the installation of charging stations for EVs across the country. The

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[355] https://www.mckinsey.com/capabilities/sustainability/our-insights/net-zero-spain-europes-decarbonization-hub
[356] Note that infrastructure investment is only a part of this investment amount.
[357] European Commission (2022), Study providing analytical support for the financial instruments and programmes to facilitate investment in the energy sector, available at: https://op.europa.eu/s/xSwf
[358] European Commission (2022), Study providing analytical support for the financial instruments and programmes to facilitate investment in the energy sector, available at: https://op.europa.eu/s/xSwf
[359] https://www.kfw.de/About-KfW/Newsroom/Latest-News/Pressemitteilungen-Details_618240.html

investment is planned to be realized over the course of the next three years until 2025.[360] This is foreseen as **direct investment** by the federal government, that will most likely be implemented through competitive bidding.

- The French Government also announced a disbursement of funds[361] through a **tender procedure** for two projects to build the necessary **port infrastructure** capable of supporting the industrial activities related to floating wind power plants.[362]

Beyond the initiatives of the EU MSs governments, Textbox 9-9 and Textbox 9-10 present two examples of public funding for overcoming infrastructural barriers in the areas of electrification and enabling infrastructure for offshore-wind electricity production in the USA. Textbox 9-9 illustrates an initiative by the US Government, comprised of several programmes offering **grants and loans,** to finance the reinforcement of the electricity grid to accommodate the supply of renewable energy, to adapt it to the effects of climate change, to increase its flexibility and to build high-voltage transmission line.

Textbox 9-9 Building a Better Grid Initiative to Upgrade and Expand the USA Electric Transmission Grid[363,364]

Building a Better Grid is an initiative of the Department of Energy (DOE) of the USA, launched in January 2022, with the purpose of accelerating the development of new high-capacity transmission lines and the upgrade of the existing one, through the nation. Thus, DOE will support the building of long-distance, high-voltage, flexible and resilient transmission facilities through collaborative transmission planning, **innovative financing mechanisms**, coordinated permitting, and continued transmission related research and development.

Examples of programmes supported by Building a Better Grid:

- **Transmission Facilitation Program** (USD 2.5 billion) – develop nationally-significant transmission lines, improve access to renewable energy and increase resilience. Under the programme, DOE is authorized to **borrow** the funds through capacity contracts, loans and participation in public-private partnerships;
- **Grid Resilience Formula Grants** (USD 2.3 billion) – provides **grants** to States, territories and Tribes to strengthen America's power grid against the climate change effects;
- **Grid Resilience and Innovation Partnership programme** (USD 10.5 billion) – **grants** to improve grid flexibility and develop the transmission and distributions infrastructure through technologies such as dynamic line rating, flow control devises, advanced conductors and network topology optimization to increase the operational transfer capacity transmission networks;
- **Transmission Siting and Economic Development Grants programme** (USD 760 million) – **grants** for siting authorities to facilitate their processing of requests to permit and site certain high-voltage interstate or offshore electricity transmission lines.

Investment in grid reinforcement and flexibility, also through broad grid digitalization, will be crucial for the widespread of electric mobility, both private and commercial. Much of this investment will involve installation of high-voltage transmission lines to support the public charging infrastructure for electric vehicles, especially as the demand for smart charging increases.

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[360] https://www.reuters.com/business/autos-transportation/germany-spend-63-bln-euros-push-electric-car-charging-points-2022-10-19/

[361] Currently at the level of expression of interest.

[362] https://www.rivieramm.com/news-content-hub/france-unveils-plan-for-offshore-wind-in-the-mediterranean-plans-sector-deal-70206

[363] https://www.federalregister.gov/documents/2022/01/19/2022-00883/building-a-better-grid-initiative-to-upgrade-and-expand-the-nations-electric-transmission-grid-to

[364] https://www.energy.gov/gdo/building-better-grid-initiative

Textbox 9-10 illustrates a grant program of the US Department of Transportation that funds infrastructure project for ports, including for projects that further the offshore wind energy production.

Textbox 9-10 USA Government funds port projects to advance offshore wind energy production[365]

At the end of 2022, the US Department of Transportation (DOT) announced the deployment of USD 703 million to fund 41 projects for improving port facilities. The funds are released through the Maritime Port Infrastructure Development Programme (PIDP). Of the total deployed amount, USD 100 million is dedicated to port infrastructure development to advance offshore wind energy production. PIDP is a **discretionary grant program** administered by the Maritime Administration. Funds for the PIDP are awarded on a competitive basis to projects that improve the safety, efficiency, or reliability of the movement of goods into, out of, around, or within a port.

Examples of wind port projects that received **grants** in 2022:

- Salem Wind Port Project in Salem, Massachusetts (USD 33,835,953)
- Bridgeport Port Authority Operations and Maintenance Wind Port Project, Bridgeport, Connecticut (USD 10,530,000)
- Lake Erie Renewable Energy Resilience Project, Monroe, Michigan (USD 11,051,586)
- Arthur Kill Offshore Wind Terminal Project Staten Island, New York (USD 48,008,231)

In Spain, as occurs with certain European funds, IDAE finances projects in the frame of infrastructure development in different areas. Some examples include:

- Charging infrastructure: IDAE has developed various calls to increase the number of charging stations in Spain (e.g. **MOVES II**, **MOVES III**, **MOVALT Infrastructura**),[366] some of them included in the PERTE VEC, providing grants for the acquisition of private and public stations, including conventional, fast and ultra-fast charging points.
- Test platforms and port infrastructures for offshore wind energy: the recent "**Renmarinas Demos**" call was launched to promote activities related to testing platforms and technology demonstrators in the field of offshore wind energy. The different programs regarded under this call consist of grants in which the aid intensity depends on the entity (from 100% for research bodies, to lower figures depending on the size of the company).

In the frame of the PERTE NAVAL, calls have been launched by the ministry of industry, trade and tourism to transform the naval industry through its diversification towards offshore wind energy, digitalization, and the increase of its environmental sustainability, as well as the improvement of employee education and training. More than EUR 300 million will be destined to finance projects oriented to diversification (innovation in the value chain), digitalization (digital transformation of the chain) and sustainability (circular economy, energy efficiency, environmental improvement).

Recommendations on possible actions

In the case of Spain, the nature of the needed infrastructure falls primarily under the competency of the local, regional, and national governments.[367] For instance, the electricity transmission network in Spain

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[365] Maritime Administration (2022). https://www.maritime.dot.gov/newsroom/biden-harris-administration-announces-more-703-million-improve-port-infrastructure

[366] IDAE. Ayudas y financiación para movilidad y vehículos https://www.idae.es/ayudas-y-financiacion/para-movilidad-y-vehiculos

[367] For instance, the ports and the electricity transmission network are mostly under state control.

is in the hands of a single company[368] which is state controlled through 20% of the shares, while the rest of 80% are publicly traded. This could be an advantage for quickly coordinating and attracting investments, as opposed to the case in which several dominant stakeholders would need to agree on an investment decision. Thus, public authorities would be most engaged in ensuring the needed infrastructure investments and, as such, the state general budget and the Energy Efficiency Fund through the resources managed by IDAE are the primary candidates to support these investments (see Annex II, section 11.4).

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[368] Redelectrica: https://www.ree.es/en/activities/grid-manager-and-transmission-agent

10 Annex I List of interviews

In total, 21 interviews were conducted, incorporating the perspective of 24 sectoral actors. The interviews were conducted virtually between 9 February and 13 March 2023. Permission was requested to include the name of the association/company and the interviewee in this document, clarifying that the expressions made would not be published as quotations.

The list of organisations and actors interviewed is summarised in Table 10-1 below.

Table 10-1 List of organisations and stakeholders interviewed.

Organisation	Interviewees
Renewable Energies	
APPA - Association of Renewable Energy Companies	José María Martínez Moya, Director General
Energy Storage and Electric Mobility	
AEPIBAL - Spanish Association of batteries and energy storage	Luis Marquina, President
ASEALEN - Spanish Energy Storage Association	Raúl García Posada, Director General
AEDIVE - Business Association for the Development and Promotion of Electric Mobility	Arturo Pérez De Lucía, Director General
Batteryplat	Jesús Palma, Director General
	Francesco Paolo Gramendola, Technical Secretary
Batiq	Igor Cantero, General Manager
Hydrogen	
Aeh2 - Spanish Hydrogen Association	Rafael Luque, member of the association
Ariema	Rafael Luque, Director General
Tech Clan	Francisco Montalbán, Director General
Hiperbaric	Carole Tornello, Business Development Director General
INGETEAM	Jon Larrañaga, General Manager of Business Development
Solar Energy	
UNEF - Spanish Photovoltaic Union	José Donoso, Director General
ANPIER - National Association of Photovoltaic Energy Producers	Miguel Angel Martínez-Aroca Pérez, President
Solar Alusin	Javier Fernández-Font, Director General
INGETEAM	Jon Larrañaga, General Manager of Business Development
Wind Energy	
AEE - Spanish Wind Energy Association	Juan Virgilio Márquez, Director General
Windar Renewables	Roberto Presa, Operations Director
Siemens Gamesa	Jon Lezamiz Global, Head of Public Affairs
Navantia	Francisco Javier Herrador del Río, Director of Navantia Seanergies
	Abel Méndez Díaz, Commercial and Business Development Director of Navantia Seanergies.
	Elena Corrales Estarico, Head of Innovative Ecosystem, Navantia Seanergies
Heat pumps	
AFEC - Association of Air-Conditioning Equipment Manufacturers	Marta San Román, Director General
Airzone	José Miguel Peña, Product Quality and Energy Manager
Daikin	Ivan Martín, Head of legal environment department
Ecoforest	Miguel Prada, Sales Manager Spain

11 Annex II

11.1 EU, international and national instruments for upskilling and reskilling

Table 11-1 EU funding instruments for upskilling and reskilling. Source: Adapted from EC (2022)[369]

Access type	European Programme/Fund	Application process	Scope regarding skills	Expected 2021-2027 (total budget of programme /fund)
Financial intermediary	Invest EU[370]	Through the EIB, implementing partners and financial institutions in MSs Repayable finance including debt and equity finance.	The Social investment and skills window (SISW) will cover both the demand and supply side of skills. Support will target students and learners, SMEs and mid-caps as well as providers of training.	InvestEU: €26.2 billion
	EFSI 2 Skills and Education Guarantee Pilot[371]	Through the European Investment Fund and financial intermediaries in MSs Debt finance instruments	The Skills and Education Pilot is a new debt financing initiative dedicated to stimulating investments in education, training and skills. Final beneficiaries include students and learners, SMEs, mid-caps and training providers.	SISW: €2.8 billion
European Commission	ESF+ EaSI Strand	Grants	Support for innovative approaches in the field of upskilling and reskilling	€676 million
	European Globalisation Adjustment Fund (EGF)	Grants Applications through national authorities	Upskilling and reskilling of workers at risk of losing their job due to globalisation, as a result of a restructuring event at local level	a maximum annual amount of €186 million
	European instrument for temporary Support to mitigate Unemployment Risks in an Emergency (SURE)	Loans	SURE exclusively supports national short-term work schemes (i.e. salary compensation for reduced working time). Where envisaged under STWS, SURE can provide also support to upskilling and reskilling measures for workers benefitting under the schemes.	up to €100 billion
National authorities	Recovery and Resilience Facility (RRF)	Grants and loans Process closely linked with European Semester and each country's RRP	Development of skills to support green and digital transition and resilience	€672.5 billion
	REACT-EU (Recovery Assistance for Cohesion and the Territories of Europe)	Additional resources for the ESF/ERDF 2014-2020	Skills development and relevant infrastructure and equipment linked to fostering crisis repair in the context of the COVID-19 pandemic and preparing a green, digital and resilient recovery of the economy.	€47.5 billion
	European Social Fund Plus (ESF+ under shared management)	Grants	Modernising education and training systems. Promoting equal access to quality and inclusive education and training. Providing flexible upskilling and reskilling opportunities for all. Anticipating new skills requirements based on labour market needs.	€87.3 billion

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[369] https://ec.europa.eu/social/main.jsp?catId=1530&langId=en

[370] https://investeu.europa.eu/index_en

[371] https://www.eif.org/what_we_do/guarantees/skills-and-education-guarantee-pilot/index.htm

Access type	European Programme/Fund	Application process	Scope regarding skills	Expected 2021-2027 (total budget of programme /fund)
	European Regional Development Fund (ERDF)	Grants	Infrastructure and equipment for education and training. Development of skills supporting industrial transformation and smart specialisations.	€200.4 billion
	Just Transition Fund (JTF)	Grants	Development of skills focused on reskilling of workers in regions affected by economic and environmental transition	€17.5 billion
	Erasmus+ (new MFF)	Through national authorities (mobility and strategic partnerships) Through EC (dedicated calls) Grants	Learning mobility of learners and staff (trainers, people responsible for upskilling in reskilling) Strategic partnerships working on new and better solutions supporting upskilling and reskilling Projects defining cooperation models with SMEs to support upskilling and reskilling Blueprints for Sectoral Cooperation Centres of Vocational Excellence	
	European agricultural fund for rural development (EAFRD)	Grants	Knowledge exchange and information in rural areas	€95.5 billion

**Note: Funding instruments are based on Commission proposals (subject to changes).*

Table 11-2: Examples of support schemes to upgrade human capital

Instrument (Country)	Type / Sector	Description	Scale
Offshore Wind Workforce and Skills Development Grant Challenge (US)	Grant Scheme / Offshore wind	The Offshore Wind Workforce and Skills Development Grant Challenge is a competitive funding opportunity that will award grants to launch or expand workforce development and skills training programs focused on strengthening and diversifying the New Jersey offshore wind workforce.	$3,725,000, with individual awards ranging from $100,000 to $1,000,000.
Home Decarbonisation Skills Training Competition (UK)	Grant Scheme / Renovation (insulation, heat pumps)	The competition aims to increase supply chain capacity, both in terms of volume and skill level, by supporting programmes providing free or subsidised training for people or who want to work, in the energy efficiency, building retrofit and low carbon heating sectors.	£9,200,000, with maximum £1,000,000 per project
BUILD UP Skills Spain Construye 2020 (Spain)	EU Grant	The aim was to provide building workers in Spain with the competences and skills required in the fields of Energy Efficiency (EE) and Renewable Energy Systems (RES) in order to contribute to achieve 2020 energy objectives. As part of this programme, several trainings and didactical resources were developed; existing trainings and qualifications were upgraded and vocational education and training (VET) system was enhanced in topics including solar PV installation, operation & maintenance, among others.	EUR 826.770 (EU contribution: 75%)
Subvenciones para la financiación de acciones formativas dirigidas a personas trabajadoras (Spain)	Grants	The grants awarded under this call will be aimed at financing training programs developed by different entities and aimed at working people, both employed and unemployed. Renewable energies, innovation and development, or green transition are among the lines of action established.	EUR 66.816.112

Formación para el sector energía (Spain)	Training Programs	These training programs are designed to improve the skills and capabilities of professionals in the energy sector, focusing on different energy-related areas (solar thermal energy, renewable energy management, design of photovoltaic systems...). This training is 100% subsidized by the Public Employment Service (SEPE).	N/A

11.2 Examples of RD&I support

Table 11-3 Examples of support schemes to for RD&I

Instrument (Country)	Type	Description	Scale
SOLBAT - All-solid-state lithium-metal anode batteries (UK)	Grants	SOLBAT was established to address fundamental research challenges facing the realisation of solid-state batteries. Significant progress has been made including understanding the role of voiding at the lithium-solid electrolyte interface on discharge, and the mechanism of lithium dendrite ingress and crack propagation/short circuit on charge; developing and implementing of a new method of solid electrolyte materials discovery; and understanding the effect o volume change in composite cathodes.	£16.300.000
ReLiB - Recycling of EV lithium-ion batteries (UK)	Grants	ReLiB aims to devise and develop alternative recycling routes that could provide UK businesses with a competitive advantage. At the heart of the ReLiB approach is fast, efficient pack dismantling - facilitated by the implementation of automate disassembly, testing and sorting - and a blend of physical, chemical and biological techniques, targeted at recycling up to 100% of the EV battery efficiently and economically for the full range of battery compositions currently in use.	£14.100.000
Green Enterprise funding (Ireland)	Grants	The EPA's Green Enterprise: Innovation for a Circular Economy is an annual funding call to support innovators in Ireland to develop, demonstrate and implement circular economy approaches in their business models. It is managed through the EPA's National Circular Economy Programme and is co-funded by EPA Research.	EUR 650.000 (Projects between EUR 50.000-100.000)
TKI Wind op Zee (Netherlands)	Grants and Subsidies	The TKI Wind op Zee stimulates the development of offshore innovations through research, development, and demonstrations in order to enable offshore energy to make a significant contribution to the energy transition, focusing on three aspects related to renewable electricity at sea: cost reduction and optimisation, energy system integration and integration into the environment.	Depending on the project.
Programme des Investissemen's d'Avenir (France)	Grants (refundable and non-refundable) and Equity investment	The PIA Programme, launched in 2010 by the French government, aims to support economic growth, investing in R&D and innovative projects, technological research institutes, technology transfer companies and clusters. The French Agency for the Environment and Energy Management (ADEME) has overseen four investment programmes to support testing in real conditions and demonstration plants for renewable energy and green chemistry, low carbon vehicle, smart grid, and circular economy projects.	Min EUR 2.000.000 per project.
Energy Research Programme (Germany)	Grants	T^{he} 7th Energy Research Programme is designed to help companies and research establishments to research and develop technologies for the energy supply of tomorrow. It is a strategic element of the Federal Government's energy policy that aims to support this continuous research and innovation process. Assistance is aimed primarily at technologies that meet the requirements of the energy transition.	Depending on the project.

Instrument (Country)	Type	Description	Scale
Innovation Credit (Netherlands)	Loans	The Innovation Credit is a direct loan that enables beneficiaries to finance part of their innovative project costs. One of the focus themes are Technical Development projects. These are activities in an experimental phase aimed to develop new products or services which have substantial technical risks. These projects must lead to new market-ready products, processes or services that generate sufficient turnover to be able to repay the credit.	EUR 60.000.000 (Between EUR 150.000 - 10.0000.000)
Proyectos Estratégicos Orientados a la Transición Ecológica y a la Transición Digital (Spain)	Grants	The purpose of these grants is to promote R&D&I activities in order to increase the competitiveness and international leadership of Spain in the fields of science and technology through the generation of scientific knowledge, by means of quality research aimed at the ecological transition and the digital transition.	EUR 296.072.000
Misiones Ciencia e Innovación (Spain)	Grants	This call, included among the actions foreseen in the National Plan for Recovery, Transformation and Resilience, focuses on strengthening technological capabilities for safe and sustainable energy autonomy (fusion, hydrogen, and renewables) as well as promoting the Spanish industry in the industrial revolution of th^{e} 21st century.	EUR 125.000.000 (Projects between EUR 4-10 million or EUR 1,5-3 million for SMEs)

11.3 Examples of support schemes for manufacturing and recycling activities

Table 11-4 Examples of support schemes to for manufacturing and recycling activities

Instrument (Country)	Type	Description	Scale
Demonstration manufacturing Plant for large Scale Production of Li-ion Batteries (Sweden)	Loan	Construction and operation of a first-of-a-kind demonstration plant in Sweden, for the manufacturing of li-ion batteries. The facility serves to show the commercial viability of the concept and to qualify and industrialize products.	EUR 52.500.000
EIB Venture debt (EIB)	Secured or unsecured loans (including contingent/participating loans)	Long-term venture debt product to address the funding needs of fast-growing innovative companies. The financing structure includes bullet repayment and remuneration linked to the equity risk of the investees and complements existing venture capital financing.	N/A
InnovFin Energy Demo Projects (EIB)	Loans, loan guarantees or equity-type	InnovFin Energy Demonstration Projects (EDP) provides financing to innovative demonstration projects in the fields of energy system transformation, including but not limited to renewable energy technologies, smart energy systems, energy storage, and carbon capture utilisation and storage	Projects between €7.5 million and €75 million
Ayudas del plan de modernización de la máquina herramienta de la PYME (Spain)	Grants	The objective of this call is to support investment to expand the production capacity of existing facilities, diversify the current production of these facilities or change the production processes.	EUR 50.000.000 (Up to EUR 175.000 per machine purchased)
Reindustrialización y Fortalecimiento de la Competitividad Industrial (Spain)	Loans	The General Secretariat for Industry and Small and Medium-Sized Companies has established as a main objective that the industrial sector should continue to make a significant contribution to the GDP. In order to stimulate industrial development, a regulatory framework has been approved for the financing of investment projects to improve industrial competitiveness or contribute to reindustrialization.	Up to 75% of the project
Fondo FAIIP: Apoyo a la Inversión Industrial Productiva (Spain)	Direct Loans	FAIIP finances entities that develop industrial activities or services (regardless of their size), focusing on environmental sustainability. The creation or relocation of industrial establishments, and the improvement of production lines and processes are among the lines of action contemplated in FAIIP.	EUR 1.800.000.000 (Projects between EUR 200.000 - 60.000.000).

11.4 Examples of support schemes for infrastructure development

Table 11-5 Examples of support schemes for infrastructure development

Instrument (Country)	Type	Description	Scale
CEF Transport (EU)	**Grants** that can be combined with **loans** or investment facilities from financial institutions	It aims to support investments in building new transport infrastructure in Europe or rehabilitating and upgrading the existing infrastructure	EUR 25.8 billion
CEF Energy (EU)	**Grants** that can be combined with **loans** or investment facilities from financial institutions	The focus is on cross-border renewable energy projects, interoperability of networks and better integration of the internal energy market.	EUR 5.84 billion
InvestEU Fund, policy window sustainable infrastructure	The InvestEU Fund provides EU budgetary **guarantee** to support implementing partners (EIB and EIF) to increase their risk bearing capacity to provide financing, in the form of debt or equity, to final beneficiaries addressing EU policy priorities.	InvestEU supports activities of strategic importance to the EU, in particular in view of enhanced resilience and strengthening strategic value chains.	EUR 9.9 billion
Cohesion Fund	MSs can use the contribution from the CF to provide **grants, loans, guarantees, equity, quasi-equity, prizes or a combination thereof**. MAs can tailor financial products according to their needs or structure the financial instrument based on terms and conditions provided by the EC for 'off-the-shelf' instruments	Among other policy objectives, relevant for the measure at hand, it supports the transition to circular economy, sustainable urban and cross-border mobility.	EUR 48 billion
European Regional Development Fund (ERDF)	**Grants, prizes and combination** of financial instruments	Policy objectives 1 and 2 under this funding programme are concerned with making Europe more competitive, by promoting innovative and smart economic transformation, and greener by supporting the transition towards net-zero carbon economy. Both of these objectives can be fulfilled by investments in infrastructure development in, for example, recycling facilities, facilities for assembling components for renewable energy installations, infrastructure needed for the promotion of electric mobility etc.	EUR 274 billion + EUR 8 billion Interreg programmes
Just Transition Fund (JTF)	The JTF primarily provides **grant** financing; however, private investments can be garnered through InvestEU and public financing can be leveraged through the EIB.	A specific type of project financed under the JTF refers to infrastructure development for affordable clean energy, including energy storage technologies. However, it should be taken into account that, under	EUR 7.5 billion under the MFF for 2021-2027 + EUR 10 billion from the European Recovery Instrument for 2021-2023

Instrument (Country)	Type	Description	Scale
		the shared management with the national and regional authorities, the European Commission, together the MSs, will identify the territories and sectors eligible for funding under the JTF and that the project selection criteria are identified individually by the Member States.	
Ayudas para proyectos en inversiones en sistemas de producción de energía limpia (Spain)	Grants (reimbursement of eligible costs actually incurred)	The call supports the creation, improvement, and extension of infrastructures in rural areas, promoting local investments in infrastructures for clean energy generation systems for self-consumption.	EUR 1.000.000

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