Orkestra
BASQUE INSTITUTE
OF COMPETITIVENESS
DEUSTO FOUNDATION

CUADERNOS ORKESTRA
ISSN 2340-7638
https://doi.org/10.18543/RTWM2847

THE VALUE OF ELECTRICITY GRIDS FOR THE COMPETITIVENESS OF THE BASQUE COUNTRY

No. 01/2025
https://doi.org/10.18543/ZHAX2253

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CUADERNOS ORKESTRA, no. 01/2025

ISSN 2340-7638

Collection: https://doi.org/10.18543/RTWM2847

Notebook in Spanish: https://doi.org/10.18543/IZOB2814

Executive summary in Basque: https://doi.org/10.18543/SSPU1226

Notebook in English: https://doi.org/10.18543/ZHAX2253

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Acknowledgements

The authors would like to thank all the people/institutions that participated in the review of an earlier version of this paper, in particular Roberto Álvaro Hermana from REE, Maider Bilbao Ozámiz from Ormazabal, María del Carmen Delgado López from Loyola University, Leonardo Hervás from CIDE, José Ignacio Hormaeche from Clúster de Energía, Unai Alaña, Javier Arriola, Isabel Loureiro and José Javier Rodríguez from Iberdrola for their review of a draft of this paper; Mikel Albizu Echevarria and Itziar García Blázquez of Orkestra for providing us with data on occupations and knowledge and skills associated with sectors related to electricity grids; Ibon Gil de San Vicente and Ander Sánchez Maudo, also from Orkestra, for the information provided on the ownership of companies in the capital goods manufacturing sector, Nahia Martínez Vozmediano for her collaboration in compiling economic information on the companies in the Basque Country Energy Cluster, and Jokin Txapartegi for his help in the editing and final review of the document.

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The original language of this document is Spanish. The translation was done using DeepL.

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Executive summary

Without adequate planning and investment in electricity grids, it will not be possible to integrate renewables into the electricity system or other infrastructures related to hydrogen and the capture, storage and use of CO_2. Without this, it will not be possible to progress towards decarbonisation, nor will it be possible to cover the increase in demand resulting from greater electrification of transport, industry or buildings.

The impact that the development of electricity grids can have on the competitiveness of a territory is determined by its structural context. In the case of the Autonomous Community of the Basque Country, industry is particularly important and requires guaranteed and quality access to safe and clean energy. Furthermore, the territory has a business and R&D&I sector that is highly specialised in electricity grids.

The Basque Country Energy Cluster has more than 80 companies and entities in the field of grids (energy operators, equipment and component manufacturers, engineering companies, service companies, agents of the Basque Science, Technology and Innovation Network and public agencies of the Basque Government) which, in 2022, employed around 6,222 people, with sales of 18,000 million euros, and an investment of 78.6 million euros in research and development (R&D).

Value chain of electricity grids in the Basque Country

Source: own elaboration based on data from the Energy Cluster.

In order to analyse the value of electricity grids for the competitiveness of companies in the Basque Country, as well as their pull effect on other sectors and companies, and their potential for improving competitiveness and territorial wellbeing, the competitiveness analysis framework for the wellbeing of Orkestra was applied putting the focus is on: (i) economic-business results; (ii) wellbeing results; and (iii) the dynamic levers of competitiveness and wellbeing.

Economic and business performance

Investment in electricity grids directly benefits industrial sectors such as electrical material and equipment, wireless equipment, information, communication and computer technology systems and advanced analytical services such as technical, scientific and consultancy services. In 2022, these sectors accounted for around 7.78 % of the Basque Country's GDP. Exports of electrical transformers, static converters and choke coils were one of the top 25 exported items in 2023. Moreover, with respect to 2022, it was the item with the greatest increase in exports (+42 %).

Similarly, grid investment generates indirect benefits (through cost reductions) for energy-intensive industrial sectors such as: (i) metallurgy and metal products (6.59% of GDP in 2022); (ii) rubber, plastics and other non-metallic minerals (1.82%); and (iii) wood, paper and printing (0.88%). In addition, electricity grids are key to advancing the decarbonisation of thermal processes in these sectors, which will lead to an increase in their electricity demand.

Investment in renewables and electrification is expected to generally lower energy costs for companies[1]. Although this requires new investments in grids, costs are not expected to increase due to the increased use of them. Any reduction in energy prices, and in particular electricity prices, will have a positive impact on companies' margins.

The development of electricity grids is expected to have a positive impact on the trade balance; on the one hand through lower energy import costs, and on the other hand through increased exports from energy and emission-intensive sectors and from the electrical equipment sector.

Finally, investment in grids at a global level may also increase the attractiveness of the Basque Country for external investors, with foreign direct investment (FDI) being affected, in some cases, in electricity-intensive sectors that require access to high electrical power (e.g., electrolysers and data centres) and, to a lesser extent, in the sectors of electrical material and equipment manufacturing, telecommunications, consultancy and information services, and research and development. These sectors received an estimated investment of €2,304 million between 2014-2021.

Wellbeing results

Increased grid investment affects households in two complementary ways: (i) it enables lower electricity bills and (ii) it promotes improvements in residential energy efficiency.

[1] Investments in renewables and grids will facilitate the electrification of consumption (air conditioning in buildings, electric vehicles, industrial processes), which will have an impact on the reduction of GHG emissions. For many companies this will also mean cost reductions, but not in all cases. It will depend on the type of process, the associated consumption and the investments needed to electrify consumption, among others.

However, in 2022, the energy crisis boosted household energy expenditure from 6.2% on average in 2017-2021 to 7.2% of the household budget in the Basque Country.

In this context, in 2023, 11.5% of the population could not afford to keep their homes at an adequate temperature during the winter. As high energy prices are one of the determinants of energy poverty in Europe, a reduction in energy prices can contribute to its mitigation.

On the other hand, the development of distribution grids will have positive impacts in different areas. Firstly, it will empower consumers by giving them the opportunity to actively participate in the electricity system.

Secondly, it will create direct and indirect jobs in electricity distribution grids which, in many cases, have salary levels above the average for the economy (in 2021, 39,204 euros per year). In 2021, there were around 2,500 people in the electricity, gas and steam sector, of which a proportion are in the area of management and operation of electricity grids. In the field of manufacture of electrical material and equipment and computer and electronic products there were 16,535 people, in telecommunications and IT 17,417, in consultancy 38,946 and in R&D 8,681. Due to the characteristics of these positions and the necessary technological development, new learning and training opportunities will arise.

Thirdly, investment in grids will lead to a reduction in CO_2 and particulate emissions, which will improve air quality, and reduce premature deaths and costs related to pollution-related health conditions.

Dynamic levers of competitiveness and wellbeing

The dynamic levers are elements on which to act in order to improve competitiveness and which, as a consequence, have an impact on the territory's performance. The main elements related to each of them are described below.

Dynamic levers for improving territorial competitiveness associated with electric grids

Natural capital

- 581 MW renewables in 2023
- Renewables potential of 27.9% of final energy consumption in 2030
- Reduced wind power potential and solar radiation level
- Shortage of mineral raw materials

Physical capital

- 4,430 km of high and very high voltage lines
- More than 18,600 km of medium and low voltage lines
- 11,916 transformer stations in service
- 165 substations
- Service quality level above the national average
- 120 million euros of planned investment
- Adaptation to climate change

Financing

- Key to investment
- Regulated activity and remuneration
- Activity is not risk-free due to regulation
- The role of governments is essential, but governments cannot lead the financing ecosystem

Knowledge

- Need for digital technologies
- Research centres and laboratories
- Collaboration with industry for the transfer of digital technologies
- Science, Technology and Innovation Plan (PCTI)
- Scientific excellence, technological and industrial leadership and open innovation

Human capital

- Competences and skills
- Occupation: electrical, electronic and telecommunications engineers: 7,392 employees
- Professional training: professional families of electricity and electronics, energy and water, computer and communications or installation and maintenance
- Non-regulated training

Social and institutional capital

- Institutional quality
- Stable and predictable legal framework
- Regulatory innovation
- Collaboration and coordination among agents
- Social awareness
- Strategy for the communication and social acceptance of projects

Source: own elaboration.

Electricity grids are a key infrastructure that enables the valorisation of **natural capital**, one of the six dynamic levers for boosting territorial competitiveness. However, their development requires mineral raw materials (including critical or fundamental raw materials) that are not available in the territory.

Harnessing renewable resources requires new investments in the **physical capital** of grids, as well as the adaptation of existing grids to ensure their resilience to climate change. In this sense, the currently available grids were designed under the criteria of the 1970s; they are only prepared to absorb vegetative growth and not for today's high electrification requirements, both in terms of quantity and power (renewable generation, electrification of consumption, and batteries).

Therefore, measures need to be taken to: (i) strengthen connections between transmission and distribution grids; (ii) expand the 132 kV grid and upgrade the available one; (iii) develop new transformer stations and substations as well as resize and improve the efficiency of existing ones; (iv) change the layout of lines to avoid flooding areas, including the elevation and waterproofing of equipment; and (v) promote energy efficiency and the use of higher resistance conductors.

The **financing** lever is essential to guarantee the appropriate instruments to undertake the necessary investments, bearing in mind that the activity and remuneration of electricity grids is regulated. Moreover, due to its long tradition and technological maturity, it is *a priori* considered a low-risk investment. However, there are difficulties in establishing the final remuneration and cost of capital, restrictions on the volume of recognised investment and cybersecurity, among others. Governments and public institutions are key to financing, but they cannot lead the financial ecosystem. Therefore, is necessary the participation of private financial institutions (i.e., banks, investors, alternative financing, insurance companies, consultancies, rating agencies, etc.) as well as other sources, both from within the sector and from abroad (where investment attraction efforts are needed).

On the other hand, **knowledge** related to electricity grids must be fostered to accelerate the transition. The challenge is to have laboratories, industries, and universities that collaborate and transfer the knowledge generated, keep up to date, and defend their leadership. The Basque Country has a long tradition of research in all the links in the production chain of electricity grids and has numerous R&D centres, laboratories, and testing and certification facilities.

To perform activities related to electrical grids (e.g., grid technicians, computer programmers and computer systems operations technicians), it is essential to have **the human capital** and develop the *skills* that enable them to perform the work processes properly. To this end, universities and vocational training centres can contribute by providing expertise in artificial intelligence and materials science in their curricula.

In terms of **social and institutional capital**, two key elements are: (i) the quality of public institutions (which must develop an adequate legal framework and stable and predictable remuneration) and (ii) cooperation and coordination between companies and agents. The regulatory framework for electricity grids must allow for their development in order to make progress in decarbonisation and maintenance of the industry. It is also necessary to simplify and streamline procedures and develop regulatory innovation mechanisms to test new services and business models, limit risk and provide valuable information to guide future regulatory changes (such as sandboxes).

As there is social opposition to the development of energy infrastructure, including grids, it is essential to strengthen the culture and awareness of the energy transition towards decarbonisation, energy efficiency, and support for renewables.

Conclusions on the value of electricity grids

Electricity grids have an important impact on the competitiveness of the Basque Country as they have an impact on:

- Economic performance and employment: Increased revenues and added value for manufacturing and grid-related service providers, employment generation and leverage effect on other sectors.
- Energy and environmental costs: Savings on energy bills, greater supply security, reduced emissions, and compliance with companies' decarbonisation targets.
- Foreign trade and balance of payments: Lower imports of fossil fuels accompanied by higher exports of electrical and related equipment companies and increased FDI attraction.
- New business models due to innovation: Deployment of new services or business lines such as energy storage or electric heating systems, development of new value chains such as hydrogen, digitalisation, and automation of industrial processes.
- People's wellbeing: Lower energy costs and improvements in health and inclusiveness.

The above impacts are key to the transition towards decarbonisation. However, the following challenges need to be addressed in order to undertake new investments:

- Have updated grid planning for the 21st century and decarbonisation.
- Facilitating the procedures for obtaining permits by developing one-stop shops, promoting the digitalisation of the process, etc.
- Coordinate the agents in the execution processes of the works.
- To have a stable and predictable regulatory and remuneration framework; resolving, among others, existing difficulties related to the investment limit, the financial remuneration rate, the increase of anticipated investments, and the updating of unit costs.
- Develop a strategy, in partnership with business and the public, that addresses social acceptance and the elements that support it.
- Create value chain finance mechanisms.
- Promote the development of skills associated with electricity grids and talent attraction.

Overcoming these challenges will help to ensure that investment in grids goes hand in hand with efforts to deploy renewable energies. This will not only advance climate objectives but will also increase the competitiveness of companies and the territory, increasing their capacity to attract and retain economic activity with high energy consumption needs and, therefore, connection to the grids. In addition, this will allow the reduction of energy prices, the development of the manufacturing industry of electrical equipment and goods, and the promotion of innovative technologies.

All this will promote the reduction of the productivity and innovation gap, but it will only be possible if the necessary incentives (financial-economic, fiscal, market, regulatory, knowledge, and collaboration) for investment in electricity infrastructures and their value chain are implemented in time. These incentives must accelerate investment in grids to take advantage of the opportunities for decarbonisation that are already being offered by industry in the territory, and which could be lost if the grids are not developed, with the consequent impact on the competitiveness of the Basque Country.

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List of abbreviations and acronyms

ACBC	Autonomous Community of the Basque Country
ACE	Energy Cluster Association of the Basque Country
AI	Artificial Intelligence
ANR	National Regulatory Authorities
APS	Announced Pledges Scenario
ARRA	American Recovery and Reinvestment Act
BIH4C	Basque Industrial Hub for Circularity
BIMEP	Biscay Marine Energy Platform
CC. AA.	Autonomous Communities
CCUS	Carbon capture, utilisation, and storage
CLA	Labour cost per employee
CNMC	National Markets and Competition Commission
CNO	National classification of occupations
CRM	Critical raw materials
DER	Distributed energy resources
DSO	Electricity distribution system operator / Distribution system operator
EBITDA	Earnings before interest, taxes, depreciation, and amortización
EIB	European Investment Bank
EPO	European Patent Office
ESCO	European Skills, Competences, Qualifications and Occupations
EU	European Union
EVE	Basque Energy Agency

EY	Ernst & Young
FDI	Foreign direct investment
GHG	Greenhouse gas
GRIP	Grid Resilience and Innovation Partnerships Program
GVA	Gross Value Added
GW	Gigawatts
H2	Hydrogen
ICE	Internal combustion engine
ICL	Imperial College London
i-DE	Iberdrola Distribución Eléctrica
IEA	International Energy Agency
INE	National Statistical Institute
IRA	Inflation Reduction Act
IVF	Basque Finance Institute
LCOE	Levelized cost of electricity
Miteco	Ministry for Ecological Transition and the Demographic Challenge
NDP	Grid development plan
NECP	National Energy and Climate Plan
NZBISC	Net-Zero Basque Industrial Supercluster
NZE	Net Zero Emissions by 2050 Scenario
ODS	Sustainable Development Goals
PAC	Paris Agreement Compatible
PCTI	Science, Technology and Innovation Plan
PGM	Platinum group metals

PM	Particulate matter
PRTR	Recovery, Transformation and Resilience Plan
PTS	Sectoral territorial plan
RCDE-UE	EU Emissions Trading Scheme (EU ETS)
R&D	Research and development
RIS3	Smart specialisation strategies
ROA	Return on Assets
ROE	Return on Equity
RTA	Technological Advantage Revealed
SMEs	Small and medium-sized enterprises
SPRI	Basque Business Development Agency
STEPS	Stated Policies Scenario
TRL	Techonolology Readiness Level/ Nivel de madurez tecnológica
TSO	Electricity Transport System Operator / Transport System Operator
US$	United States dollars
WACC	Weighted average cost of capital
ZLS	Selected location areas

1. Introduction

1.1 The role of grids for the energy transition and decarbonisation of the economy

The development of electricity grids (hereinafter referred to as electricity grids or networks) is essential for carrying out the sustainable transition, particularly the energy transition, and for promoting and even improving the competitiveness of both businesses and the territory.

With regard to the energy transition, the World Energy Outlook of the IEA (2023c) presents the following key actions to reduce emissions by 2030 to levels that will enable the goal of restricting temperature increase to 1.5°C: tripling renewable energy capacity, doubling energy efficiency levels, increasing electrification and reducing methane emissions from fossil fuel exploitation.

Without adequate investment and planning of electricity grids, it will not be possible to integrate renewables into the electricity system[2], nor will it be viable to cover the increase in demand for greater electrification of sectors such as transport, industry[3] , or buildings. In fact, at the recent COP 29 in Baku, Azerbaijan, the need to double annual investments in electricity grids and add or renew 25 million kilometres of grids by 2030 was raised (Smart Grids Info, 2024c).

Investment in grids, specifically distribution grids, will be what will make it possible to provide flexibility to the energy system from distributed energy resources (DER), increase energy efficiency through the deployment of smart meters and the diversification of the electric vehicle charging structure, in addition to reinforcing the active role of end consumers in the system. In general, grid planning should consider and anticipate the growth of distributed resources, the decarbonisation plans of the different economic sectors, and their relationship with other energy infrastructures such as hydrogen and CO_2 capture, storage, and use (IEA, 2023a).

According to the IEA (2023a) at least 3,000 gigawatts (GW) of renewable energy projects were awaiting grid connection globally in 2022, reflecting in part that grid investment has remained static at around 300 billion US dollars (US$) per year, while investment in renewables has almost doubled since 2010. In other words, grids are becoming a bottleneck in the transition[4], and without the necessary investment or delays in the transition (due, among others, to

[2] Indeed, electricity grids are currently the main obstacle to the development of wind energy, as they are not being expanded and upgraded fast enough. Grid problems are partly related to permitting and supply chains, but also to the incentives and business models applied to grid investments. Grid operators also need to organise the requests for grid connections that they currently receive (WindEurope, 2024).

[3] According to Fraunhofer ISI (2024) the role of direct electrification in industry has been underestimated, particularly in sectors such as paper and food, where, thanks to rapid innovation, there is a wide range of viable industrial electrification technologies. It estimates that, by 2035, direct electrification could replace most fossil fuels used in industrial processes requiring heat, supplying up to 90% of heat.

[4] For example, in April 2024, more than 6,000 MW of power requested by industry in Spain were left out of the planning (Periódico de la energía, 2024).

bureaucratic or social issues), climate and energy goals may be jeopardised, thus putting the decarbonisation of the global economy and climate change mitigation out of reach.

In this context, it should be noted that grid infrastructures can take 5-15 years to be completed (planning, permitting, implementation, and commissioning), while renewable energy projects can take one to five years and less than two years for electric vehicle charging infrastructure (IEA, 2023a). Therefore, the planning and evaluation of grid investments need to be aligned with long-term energy and climate objectives, considering the need for cost-effectiveness and the fact that they may require changes and/or adaptations over their lifetime (which can be up to 40 years).

1.2 Determinants of grid investment

Distribution grids will require reinforcements and additional transformation capacity in substations to effectively integrate the expected growth in demand (due to the entry into circulation of millions of electric vehicles, the connection of new data centres, the electrification of industry, and the connection of thousands of heat pumps) and ensure the quality of supply (in the face of an increase in the penetration of renewables and self-consumption, and extreme weather events or natural disasters) (Energy and Society, 2023).

In particular, there are three types of grid investment (EY & Eurelectric, 2024): (i) increasing grid capacity to deploy renewable energy, (ii) renewing existing infrastructure[5], and (iii) integrating advanced technologies for efficient grid management and control, as well as for integrating increased current and future electricity demand. Increased demand flexibility, as well as improvements in grid management and control, could lead to lower investments than initially foreseen.

Although the focus of the work is on the distribution grids, it is relevant to discuss that significant investments will also be required in the transmission grids and the connections between the two grids. These investments will (i) provide interconnection to large *offshore* and other *onshore* wind and solar PV plants, (ii) increase transmission capacity between market areas to reduce congestion, (iii) increase the resilience of the transmission grid to climate change and the massive deployment of renewables, (iv) develop cross-border connections, and (v) integrate and support the hydrogen and carbon capture, storage, and utilisation (CCUS) grid. In parallel, it will seek to maximise the use of existing grids, allowing for shorter interventions, less processing, and reduced local impact, among others.

In terms of distribution grids, according to the classification by EY & Eurelectric (2024) the determinants of investment can be divided into six categories: (i) demand-driven

[5] Around 40-55% of the distribution network infrastructure in the EU will be over 40 years old by 2030 (Deloitte et al. Monitor, 2021).

reinforcement[6], (ii) generation-driven reinforcement, (iii) replacement and renewal, (iv) resilience, (v) digitalisation and automation[7], and (vi) smart metering (see Figure 1).

Figure 1 Determinants of investment in distribution grids

Note: Smart metering could be under the category Digitisation and automation, but due to its focus on managing the flexibility of the low voltage grid, it has been chosen to be included in a separate category.
Source: own elaboration based on ERT (2024), EY & Eurelectric, (2024), IEA (20232023a), Monitor Deloitte et al. (2021).

[6] One of the ways to decarbonise the economy is electrification. As far as industry is concerned, the current transition is leading to an increase in the demand for electricity in industrial sectors that until now had production processes dependent on fossil fuels and whose demand for electricity was very low. In this way, a substitution of these fuels is taking place, leading to an exponential increase in electricity demand.

[7] According to IEA (2024b) the digitisation of electricity grids improves their performance (reducing costs, losses and theft), reliability and security; enhances access and affordability, prepares for the future (integration of renewables, planning, etc.), optimises data management, and fosters demand management and electrification.

In this regard, and for the case of Spain, Energy and Society (2023) estimates the need for "grids capable of integrating an additional 40,000 MW of renewables, storage, 5.1 million electric vehicles, 300,000 heat pumps to electrify heating, at least 4,000 MW of electrolysers and meet the needs of a new concept of consumer". The energy transition's success will depend on facilitating investment in developing and adapting electricity grids.

However, as will be seen below, there are already difficulties in investing in grids and accessing resources for their development (e.g., cables, power electronics, etc.). In developed countries, the main barriers relate to social acceptance of infrastructure[8], permitting and administrative processes that delay project implementation, and regulatory risks that may hinder anticipated investments[9], as well as the recognition of costs due to caps on investment and rate of return. In emerging and developing economies, the main barriers are the financial health of public utilities in the electricity sector and high capital costs (IEA, 2023a).

1.3 Territorial competitiveness analysis framework for well-being

The Autonomous Community of the Basque Country (ACBC) is a territory which, throughout its history and particularly since the crisis at the end of the 1970s, which affected its industrial fabric, has developed a territorial strategy based on industry as a fundamental sector of its economy.

According to Orkestra (2021), from then until the financial crisis of 2008, the bases of the territory's competitiveness were based on achieving inclusive competitiveness, where competition is based on efficiency and innovation, under the leadership of the regional government, with a commitment to a cluster policy, technological infrastructures, and advanced training systems.

In this context and because of the COVID-19 pandemic, Orkestra proposed a new framework of analysis for territorial competitiveness for well-being, which is shown in the following figure

[8] In addition to having the necessary investments in the right timeframe, the public and the different agents involved in the development processes of electricity grid infrastructures must be involved. It is necessary for them to understand the relationship between the grids and the energy transition, in order to promote social acceptance of the infrastructures to be developed (for more information on the determinants and barriers to social acceptance of renewable energy projects see Mosquera López & Fernández Gómez (2023)).
In fact, electricity grids can be seen in a positive light for the mitigation of natural disasters related to climate change, where they serve as firebreaks after fires or blackouts, as happened in Tenerife and La Gomera, respectively. Such one-off events can contribute to the social acceptance of infrastructures.

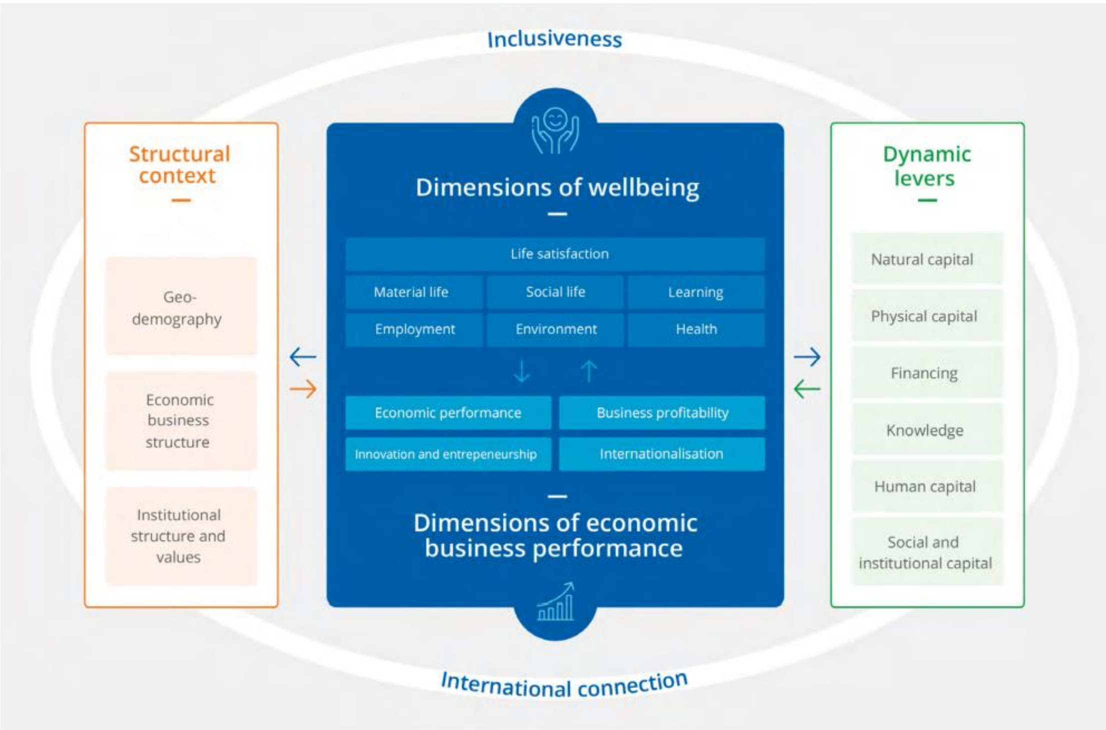
[9] Anticipated investments should be recognised and financed until the potential demand that will pay for them in the future is connected. Frontloaded investment can help grid operators achieve predictable and timely cost recognition and avoid delays. Regulators could help by developing new ways to drive innovative and digital investment, such as outcome-based regulations that favour more efficient solutions (IEA, 2024b).

Figure 2 and which constitutes the framework for analysing the value of electricity grids for the competitiveness of the Basque Country addressed in this study.

The framework is organised around economic and business performance dimensions, which have traditionally formed part of competitiveness analyses, and well-being, which, being multidimensional in nature, represent the goal of territorial competitiveness. The economic-business results reflect the results of the activities carried out in a territory and have the character of intermediate results.

On the left are those elements of the structural context of the territory under analysis. These are elements inherent to the territory, some of whose elements may be subject to a gradual change over time.

Figure 2 Territorial competitiveness analysis framework for well-being



Source: Orkestra (2021).

On the right, there are six dynamic levers of competitiveness or elements on which to act to improve competitiveness and which, as a consequence, have an impact on the territory's performance. The policies and strategies of the territory can influence these levers to mark the direction in which the territory wants to go and to promote changes in the medium and long term on elements of the structural context.

These six levers are: (i) natural capital or environmental factors that have an impact on the generation of economic value and well-being, (ii) physical capital or set of tangible assets that can also generate economic value and well-being, (iii) financial capital, (iv) knowledge and information technology assets, (v) human capital understood as training, health and participation in the labour market, and (vi) social and institutional capital as a system of rules and organisations that structure social interactions.

1.4 Aim of the study

As mentioned above, according to Monitor Deloitte et al. (2021), distribution grids are a key element for the energy transition, as they are: (i) the basis for electrification and expansion of generation capacity, (ii) the connection point for renewables requiring grid access, (iii) the enabler of flexibility and demand-side management, and (iv) the key to enabling consumer participation in the transition.

Bearing in mind the above, as well as the business capacity existing in the ACBC around electricity grids, this work aims to analyse the value of electricity grids for the competitiveness of companies in the Basque Country, as well as their tractor effect on other sectors and companies in the territory and other benefits and opportunities for improving the territorial competitiveness of the Basque Country.

To do so, it will seek to answer the following questions:

- What are the impacts of electrification and increased investment in grids on the competitiveness of Basque companies and the Basque Country as a whole?
- What are the opportunities for companies in the Basque Country in the electricity grid value chain arising from increased investment in grids globally and locally?

To answer these questions, firstly, the possible impacts of grid investment on the different elements of the territorial competitiveness framework at the service of well-being are analysed, in particular economic-business results, well-being results, and dynamic levers, with emphasis on the impact on the competitiveness of Basque companies. Secondly, the needs for investment in grids at the global, European Union, and Spanish levels are studied. This is followed by a mapping of the companies in the value chain of the electricity grids in the Basque Country, the analysis of some financial indicators, as well as an estimate of the economic multipliers of the branches of activity related to the companies in the value chain, in order to quantify the knock-on effect which an increase in the production of these branches can have on the economy of the ACBC as a whole. Finally, a series of conclusions and recommendations are presented.

2. Value of electricity grids in the light of the territorial competitiveness framework

This chapter analyses the potential impacts of grid investment on the elements of the territorial competitiveness framework for well-being (see Figure 2) where this investment is expected to have an impact, starting with the structural context, the dimension of economic and business results for all companies in the territory, followed by the dimension of well-being and the dynamic levers. The impacts on the transversal axes of inclusiveness and international connection will be considered, the first in the well-being axis and the second in the economic-business results (the trade balance) and the physical capital lever (interconnection infrastructures).

Electricity grids can influence the territorial competitiveness of the Basque Country through changes in the following economic-business and well-being results (in turn boosted by the different levers):

- (i) economic performance and employment (increase in revenues and value added of manufacturing companies and suppliers of grid-related products and services, as well as employment generation in the sector and the pull effect on other sectors[10]),
- (ii) energy costs and the environment (savings on energy bills, greater security of supply, reduced emissions, and meeting companies' decarbonisation targets),
- (iii) foreign trade (lower imports of fossil fuels accompanied by higher exports of electrical and related equipment companies),
- (iv) new business models due to innovation (deployment of new services or business lines such as energy storage, electric heating systems, smart appliances, etc.; development of new value chains such as hydrogen or the digitalisation and automation of industrial processes),
- (v) people's well-being (lower energy costs, quality employment opportunities, and improvements in health and inclusiveness).

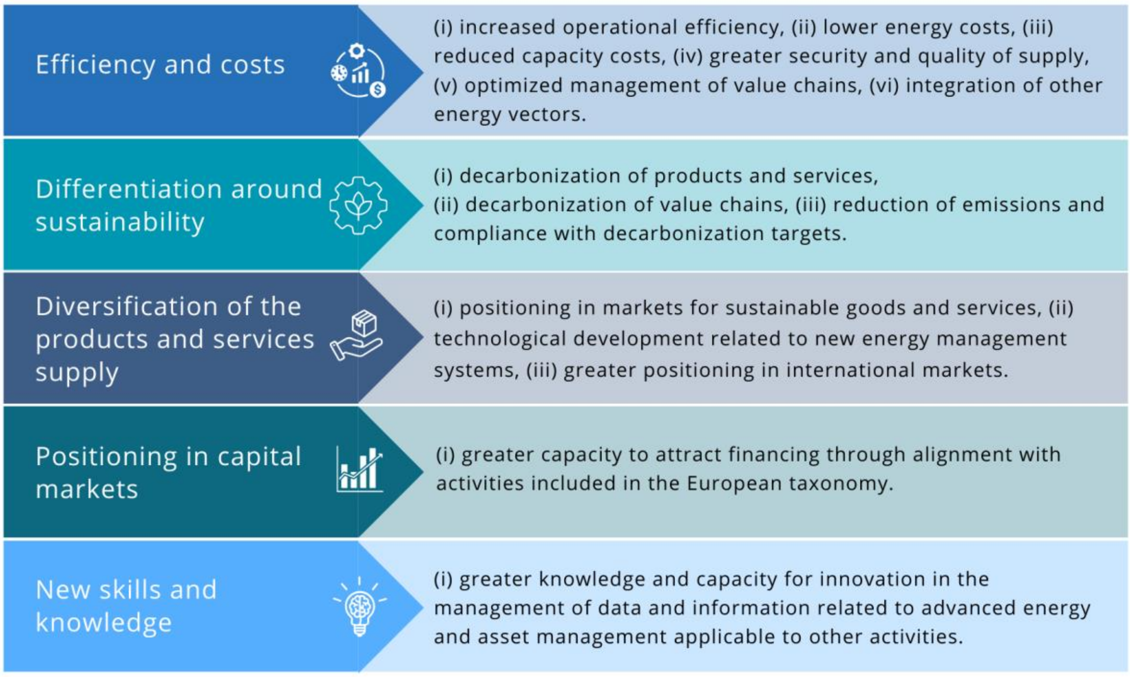
However, the analysis could also be done from a micro perspective, where the elements of business competitiveness that are affected by the development of grids are analysed. In Figure 3 presents five areas of grids ‘impact related to (i) efficiency and costs, (ii) improvements in the profitability and performance of companies through differentiation around sustainability, (iii) diversification of the supply of products and services, (iv) greater attraction of financing through improved positioning in capital markets, and (v) the development of new skills and knowledge in the specific area of grids and decarbonisation activities.

Due to the complexity of obtaining data at the enterprise level to proceed to a more detailed analysis of the impact of electricity grids at that level, this study addresses the competitiveness

[10] This study does not consider the impact of increased network investment on the construction sector in terms of civil works, given the difficulty of disaggregating the part related to grid infrastructure and because it is a minor part.

of the territory, considering elements of this analysis of enterprise competitiveness in the different sections of the territorial competitiveness framework analysed below.

Figure 3 Areas of impact of electricity grids on business competitiveness



Source: own elaboration.

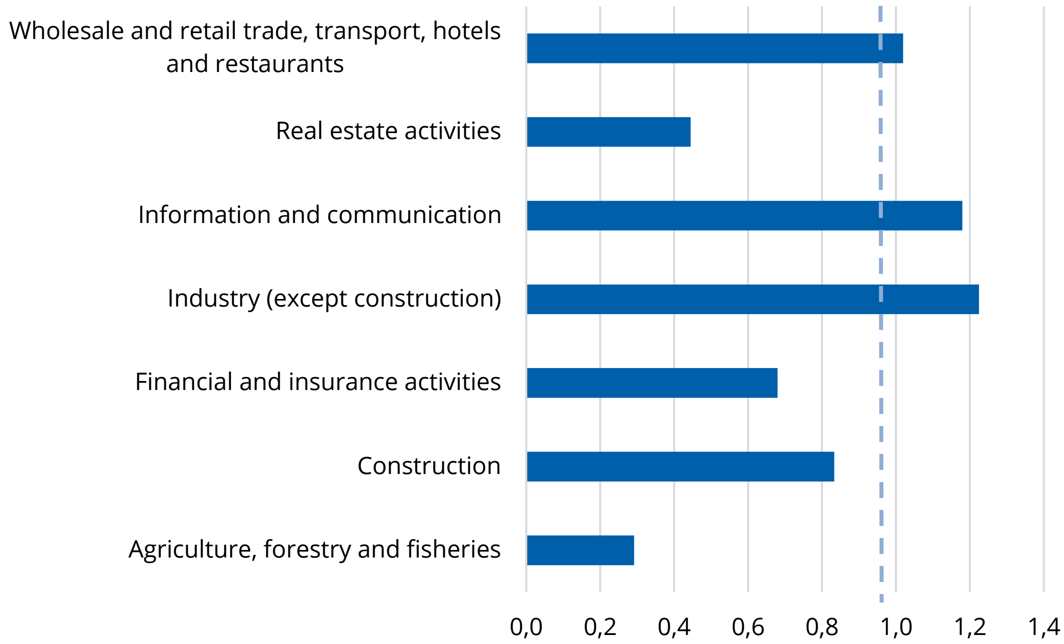
2.1 Structural context

The structural context of a territory includes the characteristics related to its geo-demography, economic-business structure, and institutional structure. These structures are stable over time, and therefore, no significant changes can be expected in the short term. However, the structural context is a determining factor in the effect that public policies or sustainable transition can have on the competitiveness of the territory (Orkestra, 2021). In turn, public policies and the processes of change resulting from transitions can affect the structure of the territory in the long term.

The geo-demographic structure of the Basque Country is characterised by a high ageing rate (23.8% of the population in 2023 was over 65 years of age, compared to 21.3% in the EU) and a working-age population concentrated in the upper age ranges. This composition of the population may negatively affect productive capacity so that positive and sustained impacts over time on economic performance, employment, and well-being of the population, derived, for example, from successful sustainable, digital, and demographic transitions, will ultimately have a positive impact on the geo-demographic composition of the Basque Country.

The economic-business structure of the ACBC presents a high degree of specialisation relative to the EU-27 in employment in two sectors: industry and information and communications (see Graph 1).

Graph 1 Sectoral specialisation ratio of the economy (2021-2023)



Note: the specialisation coefficient is calculated using the Location Quotient indicator, which is equal to the ratio between the share of employment in the sector in total employment in the Basque Country and the share of employment in the sector in total employment in the EU-27. A value higher than 1 means that the Basque Country is specialised in this activity with respect to the EU-27, and a value lower than 1 means that it is sub-specialised.
Source: own elaboration based on Eustat and Eurostat.

Disaggregating the industrial sector, Orkestra (2022) shows that the industrial specialisation of the Basque Country is mainly in manufacturing and energy activities, particularly in metallurgy and metal products. In the case of the electrical material and equipment sector, in the period studied by the report, its degree of specialisation decreased, although the Basque Country continued to specialise in this sector. In services, specialisation in research and development activities stands out, where the Basque economy is increasing its activity, and its orientation towards an economy with features of digitalisation and servitisation.

At the technological level, the degree of specialisation relative to the EU-27 in patents in the sectors of manufacture of machinery and equipment, manufacture of furniture and other manufacturing industries, and manufacture of computer, electronic and optical products is high. The other sectors with a high degree of relative specialisation in terms of employment are technologically under-specialised, with less than 15 patents per year (Orkestra, 2022).

In addition, the Basque Country is a pioneer in the cluster model, seeking to link research into technologies with the business fabric. In the area of electricity grids, the Basque Country Energy

Cluster (ACE) stands out, with 200 companies and entities (energy operators, equipment and component manufacturers, engineering companies, service companies, agents of the Basque Science, Technology and Innovation Network, and public agencies of the Basque Government). In 2022, the energy sector in the ACBC had a turnover of 15,700 million euros, 25,986 jobs, and 266 million euros in R&D (Energy Cluster, 2022).

In this way, the impact that the development of electricity grids could have on the territorial competitiveness of the ACBC is determined by this structural context, where at an economic-business level, there is a high degree of specialisation in employment, and to a lesser extent in patents, in the industrial sector, and with a strong cluster policy, which is committed to cooperation between companies, institutions, and universities.

2.2 Economic and business performance

2.2.1 Impact on GDP

Investment in power grids directly benefits industrial sectors such as electrical equipment, wireless equipment, information, communication, and computer technology systems, and advanced analytical services such as technical, scientific, and consulting services (Deloitte et al. Monitor, 2021; U.S. Department of Energy, 2013). Around €30-35 billion in investment income is expected from which EU companies in these sectors could benefit.

In the case of the economy of the ACBC, these sectors accounted for around 7.78% of GDP in 2022 (0.54% computer and electronic products, 0.73% electrical material and equipment, 1.00% telecommunications, 1.14% IT and 4.38% consultancy and technical activities) (Eustat, 2023d)[11].

In turn, investment in grids has indirect benefits for other sectors, with a notable potential impact on energy-intensive industrial sectors. In the case of the ACBC, in 2022, energy-intensive sectors such as metallurgy and metal products, rubber, plastics and other non-metallic minerals, and wood, paper, and graphic arts accounted for 6.59%, 1.82% and 0.88% of the territory's GDP respectively (Eustat, 2023d).

According to the study of the impact on the economy of the American Recovery and Reinvestment Act (ARRA) of 2009 for funding smart grid initiatives, investment in these projects positively affects the economy. Specifically, it is found that for every US$1 million in direct (public and private) investment in smart grids, GDP increased by US$2.5 to US$2.6 million (U.S. Department of Energy) (U.S. Department of Energy, 2013).

On the other hand, the study by Xu et al. (2021) analyses the effect of electricity grid infrastructure on the economic growth of regions in China. The authors find that electricity infrastructure has a greater impact on long-term growth than the short one. In addition, energy-importing regions and those with a strong industrial sector are the ones that perceive a higher level of positive impact on GDP. In this sense, it is worth noting that the Basque industry accounted for 21.81% of GDP in 2022 (18,812 million euros) (Eustat, 2023d), a figure above the

[11] For more details on the opportunities for Basque companies in these sectors, see section 3.3.

national average, which in the same year amounted to 17.43% (INE, 2023d). Thus, the higher investment in grids may translate into a higher GDP for the Basque Country.

Therefore, since the ACBC has relevant value chains for the development of the grids, the importance of the industrial sector in the economy (part of which is intensive in energy consumption) and its high dependence on foreign energy (as will be seen in section 2.2.3), investment in electricity grids and all the activity which revolves around it, take on a relevant role.

2.2.2 Impact on aggregate energy costs and business profitability

According to Monitor Deloitte et al. (2021), grid investment in the EU will ultimately lead to a decrease in companies' energy costs compared to a scenario where the necessary investments are not made (in the short term, costs will increase but at a lower level than inflation), through:

(i) a lower marginal cost of renewable generation,
(ii) the deployment of storage and self-consumption systems,
(iii) cost savings through improved flexibility and optimised energy demand management,
(iv) cost reductions through the adoption of new, more efficient electricity technologies for the decarbonisation of activities (heat pumps, electrification of fleets and processes, and medium and high-temperature heat generation, etc.),
(v) higher level of energy efficiency through greater access to real-time consumption information, optimised management of energy resources, greater flexibility and demand response,
(vi) reduction of capacity costs associated with smart grid management (e.g., flexible grid access).

For its part, P. Chaves et al. (2021) point out that the digitisation of electricity grids could reduce operating costs for electricity distribution companies by around 21%. In this regard, they point out that monitoring and control systems will make it possible to detect faults in the grid more accurately and more quickly. This will reduce the time it takes to locate possible faults and, as a result, repair them and restore supply more quickly, thus improving its quality. Likewise, maintenance strategies can be implemented thanks to monitoring equipment that can also allow for reductions in maintenance costs and even foresee unforeseen interruptions thanks to scheduled maintenance.

In the ACBC, in 2022, only the transport sector saw its energy consumption increase in volume, as well as its weight in the set, reaching 44.6% of final energy consumption in the ACBC. The rest of the sectors reduced their level of consumption. The industry, in particular, accounted for 35.3% of final energy consumption, with the remaining 20.1% divided between the residential and tertiary and primary sectors (EVE, 2023).

The industry experienced an improvement in energy efficiency (measured in terms of energy consumption per unit of GDP), which recovered 2018-2020 levels probably due to higher energy prices in 2022 (Larrea Basterra & Badajoz López, 2024). The energy consumption of electricity and gas fell, and the consumption of oil derivatives increased. Despite this, there was a significant increase in the energy bill from 6,374 million euros in 2021 to 9,149 million euros in 2022[12], i.e., an increase of 43.53% (EVE, 2023). Given this scenario, any reduction in energy prices, particularly electricity prices, will positively impact company margins.

In this line, despite the increase in investment in the grids, EY & Eurelectric (2024) estimate that consumers' grid usage costs will not increase due to the increase in grid usage. Consequently, it is considered that new grid investment will improve the competitive positioning of companies in general, and of exporting and energy-intensive companies in particular.

In this context, the costs of grid digitisation technologies are on a downward trajectory, in some cases more steeply than those of renewables and other technologies. For example, the costs of smart meters fell by 25% between 2008 and 2016, and those of sensors fell by a factor of ten in the same period (P. Chaves et al., 2021).

On the other hand, higher penetration of renewables and increased electrification of demand, as discussed below, will lead to a reduction in CO_2 emissions. Consequently, energy-intensive industries will also be able to reduce their emissions bill. Monitor Deloitte et al. (2021) estimate that reducing greenhouse gas (GHG) emissions by 50-55% compared to 1990 levels will lead to an average annual savings in the CO_2 emissions bill of EUR 17-22 billion in Europe.

The reduction of GHG emissions resulting from the penetration of renewables and increased electrification is a very relevant issue in a context where goods under the carbon border adjustment mechanism are largely traded in highly competitive global commodity markets, where the possibility to pass on the costs associated with emission allowances are limited. Therefore, plants would not operate optimally if exports are not competitive due to a higher carbon price and lower market share. With sub-optimal capacity utilisation rates, production facilities must cover fixed costs, leading to reduced profitability and financial stress. If no solution is found, a decision could eventually be taken to close those plants that are no longer profitable.

In this line, Marcu et al. (2024) found that, under certain assumptions, 63 cold-rolled steel producers would feel marginal impacts in the first years of the EU ETS reform and the phase-out of free allocation. By 2030, cost increases could translate into a significant impact, estimated at an 18% increase in overall prices. By 2034, when the carbon border adjustment mechanism comes into full force, these premiums would be 35%. With such cost overruns, there would be no room in export markets for these products, and they could significantly impact the evolution of the net operating surplus of energy- and emission-intensive sectors (see Graph 2).

Reducing emissions will allow companies to further differentiate themselves on sustainability by improving their reputation and accessing new markets for sustainable products and services, as well as improving their profitability by meeting decarbonisation targets, saving on operating costs, positioning themselves better in international markets (see section 2.2.3) and improvements in innovation (see section 2.2.4).

Likewise, greater investment in electricity grids also means an improvement in the electricity supply's security and the system's resilience to exogenous shocks such as extreme weather

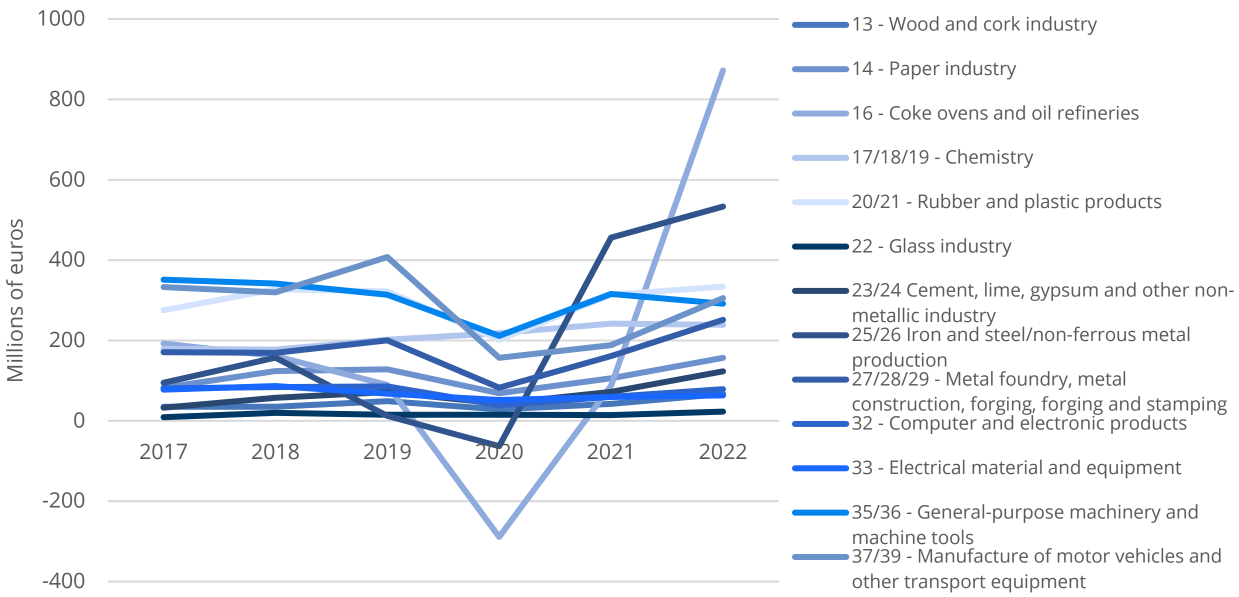
[12] Both invoices in terms of constant 2022 euros.

events or others. This increased security and quality of supply will result from predictive maintenance and rapid resolution of grid contingencies, as well as enabling the integration of self-consumption systems, electricity storage, shared risk management (e.g., energy communities), and the deployment of microgrids.

According to EY & Eurelectric (2024) the reduced likelihood of blackouts will also impact companies' energy costs, as the value of electricity when it is unavailable is more than 100 times its purchase price. For example, losses of EUR 50 billion were reported in 2021 due to blackouts in the EU (EY & Eurelectric, 2024). In this sense, in the Basque Country in 2021, energy-intensive companies had to stop their activity due to the increase in energy prices in general and electricity prices in particular (e.g., Sidenor[13] or Arcelor Mittal), with all this entailed in terms of loss of economic activity.

In this way, savings on energy bills (accompanied by greater security of supply), increases in profitability, as well as a reduction in the need for CO_2 emission allowances, will improve the competitive position and export capacity of companies.

Graph 2 Evolution of net operating surplus in energy and emission-intensive sectors and sectors related to electricity grids



Source: Prepared by the authors based on Eustat (2024b).

[13] Sidenor was paying 227 euros per MWh in October 2021, compared to just over 60 euros per MWh at the same time a year earlier (Sidenor, 2021).

2.2.3 Impact on the balance of trade and payments

The development of electricity grids is expected to have a positive impact on the trade balance. On the one hand, due to the lower cost of energy imports, and, on the other hand, due to an increase in exports of energy and emission intensive sectors as well as the electrical equipment sector. The latter is due to a possible improvement of the competitive position of companies because of a reduction of the energy bill, as just mentioned, or due to a higher added value of products thanks to investment in R&D, as will be seen in the next section.

According to the European Commission's Roadmap to a competitive low-carbon economy by 2050 (European Commission, 2011), it is estimated that energy efficiency improvements and domestic low-carbon energy production will reduce the average annual costs of fossil fuel imports by between 175 and 320 billion euros. According to a more recent study by the European Parliament, the EU is expected to reduce its fossil fuel imports by 30% by 2050, with economic benefits of between EUR 63 and 200 billion, depending on the fossil fuel price scenario taken into account (Heflich & Saulnier, 2022).

This decrease in dependence on fossil fuels, the need for which has become more relevant after the Russian invasion of Ukraine, will be made possible by the improvement and expansion of electricity grid infrastructure that will allow for the proper integration of renewable energies into the electricity grid, improve the security of supply and promote the decarbonisation of energy-intensive sectors.

Indeed, energy dependence, measured by the energy import dependency ratio[14], for total fossil fuels (solid fossil fuels, natural gas, and oil and oil derivatives) in the EU in 2022 was 62.5%, while in Spain, it was 74.3%, and 90% in the ACBC (Eurostat, 2024; Eustat, 2024a).

In terms of exports, according to Deloitte Monitor (2019), investment in electricity grids at a global level means that the electrical equipment manufacturing sector in Spain will have the opportunity to double its current activity. It is estimated that exports from the sector will increase by around 2,300 million euros per year between now and 2030. In the Basque Country, exports of electrical transformers, static converters, and choke coils accounted for 1% of total industrial goods exports, one of the top 25 exported items in 2023. Moreover, for 2022, it was the item with the highest increase in exported value (+42%).

Graph 3 shows the exports of certain groups of products from the ACBC, some of them directly related to electricity grids and others not, but which serve as an element of comparison and whose choice has been made based on their relevance for the Basque economy (e.g., oil and derivatives and iron and steel). The coordinate axis shows the variation in the share of Basque exports of these products in the national total for 2018-2023. The ordinate axis represents the share of exports in the year 2023. The size of the bubbles represents the volume of Basque exports of each product group.

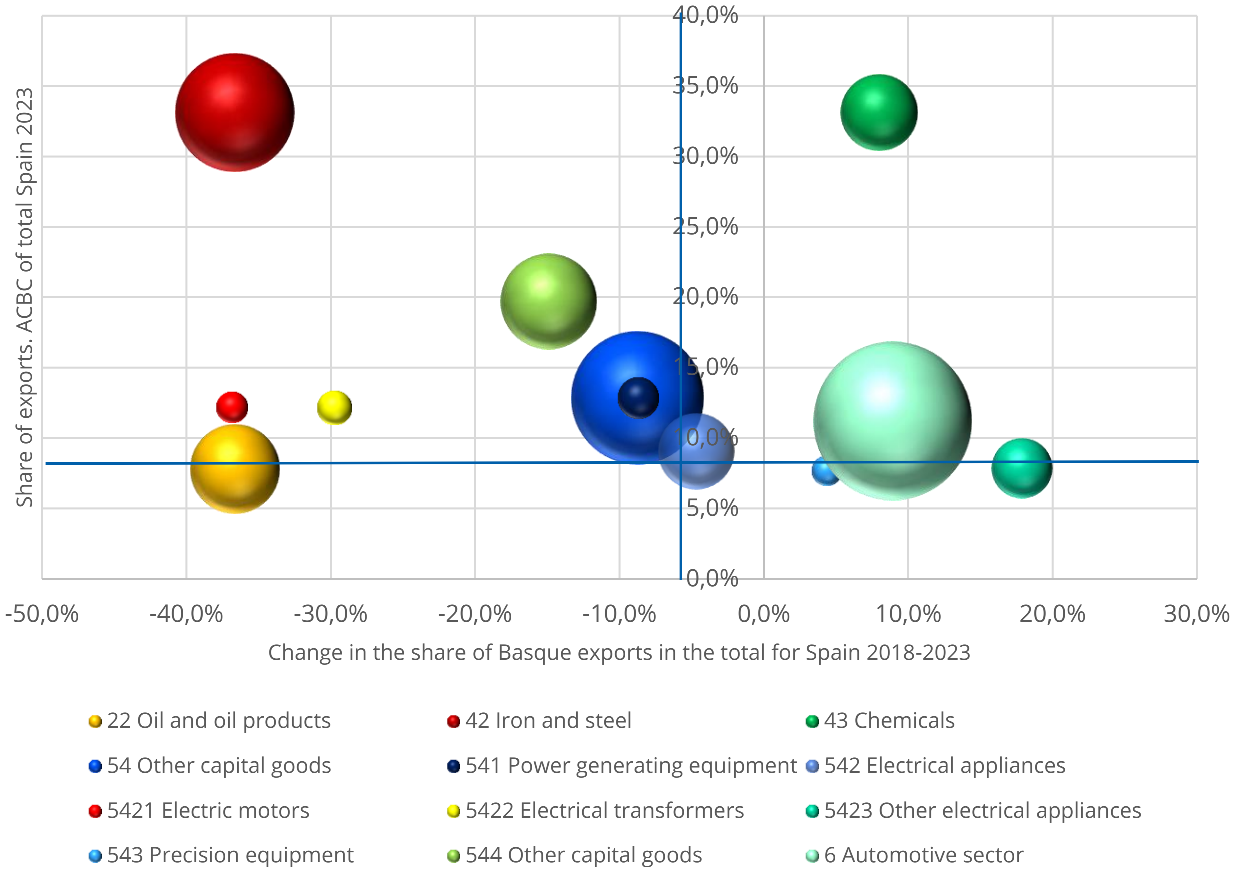
[14] Defined as net energy imports (imports minus exports) divided by gross inland energy consumption plus fuel supplied to international marine bunkers (Eurostat, 2024).

In 2018-2023, exports from the ACBC increased on average by 26.6% (34.5% in Spain). By item in monetary terms, exports from the ACBC of all the products considered in the graph have increased. Graph 3 except those of groups 22 Petroleum and derivatives and 5421 Electric motors.

The increase in exports of 541 Power generating equipment (81.8%), 542 Electrical apparatus (16.3%), and 543 Precision apparatus (43.2%) is noteworthy. Exports of 5422 Electrical transformers increased by 81.7% (nationally, this increase was 158.7%).

In the case of Spain as a whole, there was only a reduction in the case of 5421 Electric motors. Despite the above, the ACBC saw its representativeness in the country's exports fall by an average of 5.8%. Products from groups 5423 Other electrical appliances, 543 Precision equipment, and two other sectors not directly related to electrical grids, such as 42 Iron and steel and 6 Automotive sectors, increased their representativeness.

Graph 3 ACBC exports of selected product groups



Note: The axes in colour represent the average of the variables for the set of products considered.
Source: own elaboration based on Datacomex.

On the balance of payments side, global grid investment may also increase the attractiveness of the Basque Country for external investors, specifically foreign direct investment (FDI) in electricity-intensive sectors requiring access to significant electrical power (e.g., electrolysers and data centres) and, to a lesser extent, in the sectors of electrical equipment and material manufacturing, telecommunications, consulting, and information services, and research and development (see Box 1). According to estimates by Kamp et al. (2024), these sectors in the ACBC received between 2014-2021 an investment of 2,304 million euros, which is equivalent to 33% of FDI in acquisitions and expansions[15].

Box 1 Location of new companies in the territory

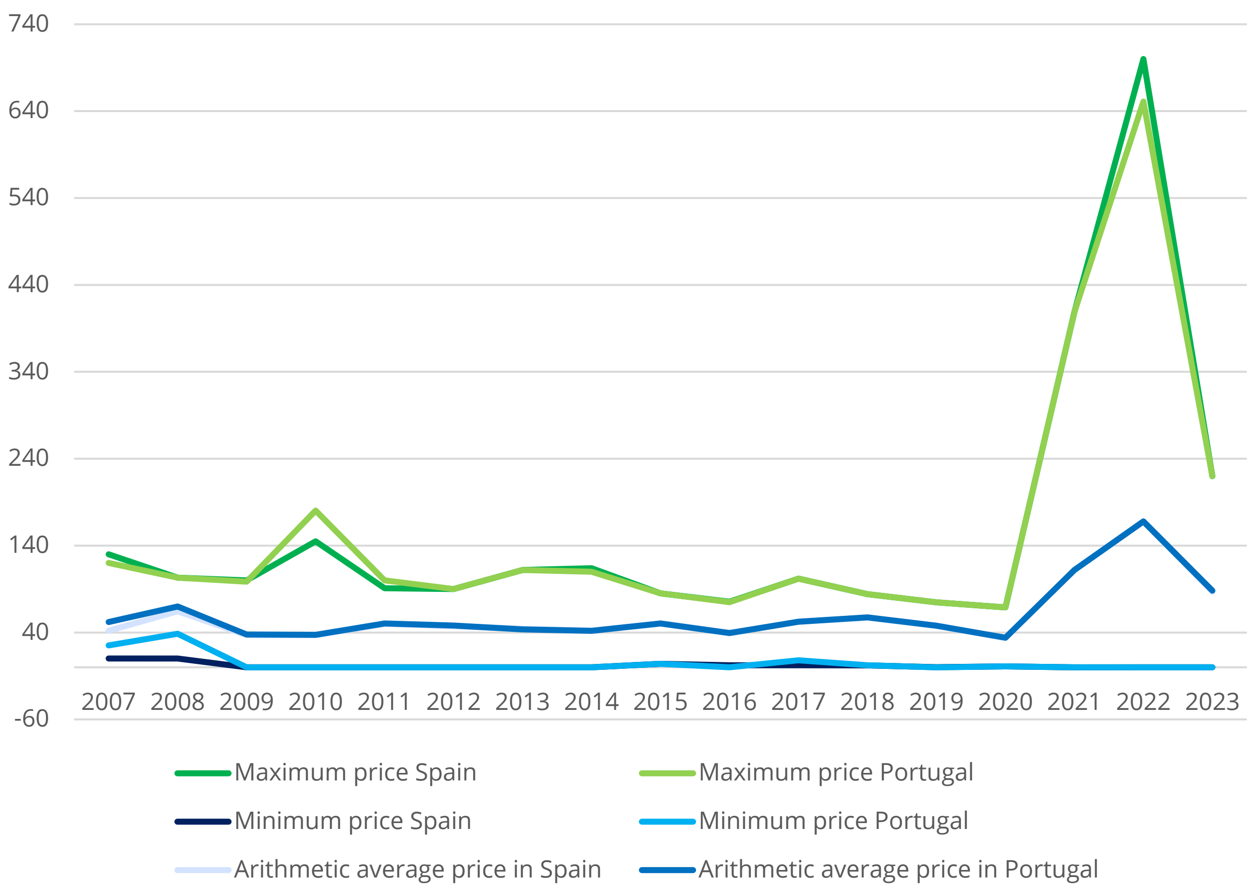
Certain conditions of the territorial context, such as investment incentives or low taxation, could attract foreign investment. Along these lines, Stokes (2024) considers that a reduction in energy prices in a territory can attract industrial activity to it, as is estimated to happen in the United States in the coming years, due to the investment produced by the Inflation Reduction Act (IRA).

In 2021-2022, during the recent energy crisis, the price of electricity in the EU was higher than in countries such as the USA or Australia (European Commission, 2024a). This may constitute a barrier to investment and even the continuation of European industrial activity. In the current context, the wholesale electricity market price in the Iberian Peninsula since 2022 has been lower than in other EU territories, as seen in Graph 4.

In this respect, given that investment in electricity grids in the coming years in Spain is expected not to lead to higher energy prices and to improve supply security, the territory could likely benefit from foreign investment, including in energy-intensive sectors.

[15] Acquisitions refer to the acquisition (complete or partial) of a company in the Basque Country by a foreign company; and expansions refer to investments to expand production capacity or facilities of foreign companies with subsidiaries in the Basque Country (Kamp et al., 2024).

Graph 4 Minimum, average and maximum price of the Mibel daily market matching (euros / MWh)



Note 1: 2007 data include July to December.
Note 2: In the first half of 2021, the upper and lower levels of the daily market matching prices were modified (-500 euros/MWh and +3,000 euros/MWh).
Source: OMIE (2024).

2.2.4 New business models linked to grid digitisation, energy management, and energy resource flexibility

Digitisation allows electricity grids to be adapted to meet various quality-of-service requirements. It also facilitates more efficient and reliable data exchange between actors (J. P. Chaves et al., 2024). It can generate value by developing new business models through technologies such as artificial intelligence (AI), the internet of things, and blockchain (P. Chaves et al., 2024).

In this sense, digitisation facilitates "access, connection and grid use of new distributed energy resources" (renewable generation, such as solar, electric vehicle charging points, heat pumps, storage batteries, etc., installed by different business agents or consumers) (P. Chaves et al., 2021). As a consequence, users adopt a more active role in their energy consumption and may opt for investment in renewable technologies (self-consumption or participation in energy communities) or energy efficiency, among others.

Digitalisation also enables the development of new business models for aggregators and service companies, which enable the integration and participation of distributed resources in markets (e.g., storage-as-a-service or local energy communities) and demand response (J. P. Chaves et al., 2024). This will encourage flexible services, which will grow in relevance in an environment where renewable energy will be key and end-user costs will be lower.

New business models linked to energy management and the flexibility of energy resources (energy storage, electric heating systems, smart home appliances, new energy management systems, demand aggregation, measurement, control, and response services, integration of renewable energies in self-consumption schemes or industrial energy communities, etc.) require a commitment to investment in innovation and technological development.

They will also enable the positioning in markets for sustainable goods and services by adopting innovative business models based on clean electric technologies, servitisation based on electric assets such as vehicles or industrial equipment, innovative mobility services with advanced data and information management, behind-the-meter services, etc.

Relevant activity has emerged around electricity grids and their digitisation related to the risk of cyber-attacks, the costs of which could be high, including the interruption of electricity supply. To avoid the risk, digitisation technologies must include elements to ensure security, such as the secure configuration of equipment, maintenance of updates, handling of access rights, training of employees, and recruitment of specialists, among others.

At the ACBC level, the Smart Specialisation Strategy (RIS3) commitment includes energy as one of the RIS3 strategic areas. As a result, as early as 2011, the EnergiBasque strategy was developed in the field of energy, focusing on eight priority strategic areas: (i) wind power, (ii) wave power, (iii) solar thermal power, (iv) electrification of transport, (v) management of energy services, (vi) energy storage, (vii) exploration of non-conventional gas[16] and (viii) smart grids. As can be seen, the areas were mainly focused on electricity as an energy vector and its connection through smart grids, with storage as an enabling technology (Basque Government et al., n.d.).

The 2021 update of the EnergiBasque strategy was organised around eight strategic areas and five technological areas (enablers), which aim to give continuity to the previous version (SPRI Group, 2022). The strategic areas are: (i) electricity grids, (ii) wind energy, (iii) solar energy, (iv) wave energy, (v) *oil & gas*, (vi) energy efficiency, (vii) electric mobility and (viii) hydrogen. The five enabling technologies are storage, circular economy, power electronics, materials, and digitalisation.

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[16] Law 6/2015 of 30 June 2015 on additional environmental protection measures for the extraction of unconventional hydrocarbons and hydraulic fracturing or *fracking* established additional environmental protection measures for the exploration, research and exploitation of hydrocarbons. Subsequently, Law 7/2021 of 20 May on climate change and energy transition prohibited new licences for the exploitation of hydrocarbons and radioactive materials, thereby losing interest in gas exploration activity in the Basque Autonomous Community.

In this sense, it can be seen how the ACBC has made a commitment to areas related to electricity grids and their digitalisation, as well as to other areas related to the new business models that may appear with their digitalisation. This, to a large extent, and as will be seen in section 3.3, is related to the industrial fabric that makes up the energy and industrial sector of the territory.

2.3 Well-being outcomes

2.3.1 Impact on energy bills

Increased investment in grids affects household energy expenditure in two ways: on the one hand, it enables lower electricity bills, and on the other hand, it allows improvements in residential energy efficiency to be made.

As mentioned in the previous section, the deployment of renewables will lead to lower electricity prices in the wholesale market, as renewables have a marginal cost close to zero, and their levelised cost of energy (LCOE) is expected to be 50% lower than that of fossil fuels (Deloitte Monitor et al., 2021). At the same time, distribution costs borne by consumers are expected to remain fixed until 2050, as higher levels of investment are offset by increasing volumes of energy consumption.

On the other hand, households are expected to gain energy efficiency gains from direct electrification using heat pumps (three to five times efficiency gains) and electric vehicles (three times efficiency gains). Savings are also expected from efficiency improvements in buildings and reduced travel distances due to changes in people's behaviour (carpooling or switching to other mobility alternatives, e.g., scooters or electric bikes). The average annual energy consumption of EU households is estimated to fall from 25 MWh to less than 10 MWh in 2050. All in all, the EU household energy bill is expected to decrease by 45% in 2050 compared to the 2018 bill (EY & Eurelectric, 2024).

These improvements should impact the household energy expenditure level, which is expected to be reduced and free up resources for other purposes[17].

In addition to this average decrease in household energy expenditure, the development of grids, especially distribution grids, will allow, as indicated above, the empowerment of consumers by enabling them to participate actively in the electricity system. Households will be

[17] However, during the recent energy crisis, the opposite effect occurred due to the increase in energy prices. In the ACBC, in 2022, household energy expenditure increased from 6.2% on average in the period 2017-2021 to 7.2% of the household budget, an additional percentage point being taken out of household budgets (Eustat, 2023b).
This conjunctural situation meant that households paid an average of 2,560.2 euros (1,090.7 euros per person). For electricity in particular, the average expenditure stood at 755.8 euros per household and 322.0 euros per person, compared to 686.4 euros and 290.4 euros the previous year. Despite this, the relative weight of the level of expenditure on electricity remained constant. The largest increase in absolute terms was for liquid fuels (44%), followed by solid fuels (35-37%), motor fuels (31-32%), natural gas (23-24%) and electricity (10-11%).

able to access self-consumption solutions (around 40 GW of additional capacity is expected), energy communities for electricity generation with renewable sources, offer flexibility services through smart charging of electric vehicles (the sustainable transition requires around 70 million electric vehicles and 56 million charging points by 2030) and demand response with the use of smart meters and smart appliances. These opportunities will further decrease household energy costs (Deloitte et al. Monitor, 2021).

Finally, this reduction in household energy bills and the opportunities to participate in the electricity system can also have a positive impact on reducing household energy poverty, as energy prices are one of the main factors that determine this social phenomenon (Mosquera López & Larrea Basterra, 2024)[18].

2.3.2 Generation of quality employment

Currently, direct and indirect jobs in electricity distribution grids represent between 0.38% and 0.46% of the EU workforce (750,000-920,000 jobs). Direct jobs are centred on the planning, operation, and maintenance of distribution grids, while indirect jobs are related to the manufacture of electrical equipment and the construction of electrical projects (EY & Eurelectric, 2024).

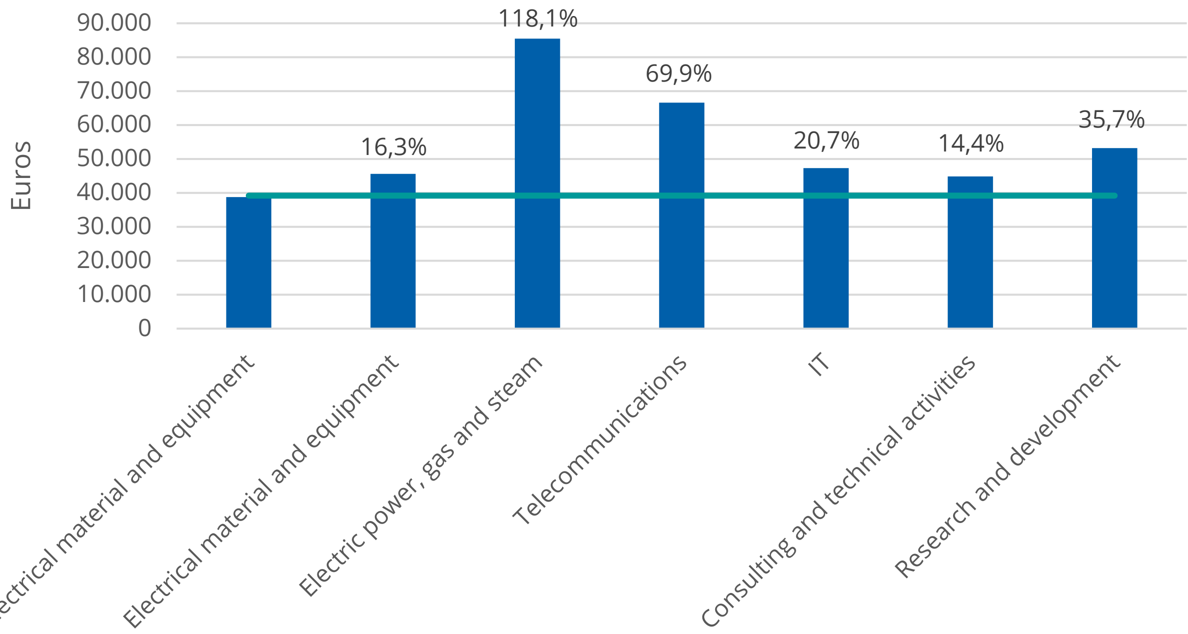
To achieve the decarbonisation targets of the EU economy, it is expected that the necessary investments in distribution grids will be made and that direct and indirect jobs will increase while new jobs will be created, especially related to the digitalisation and automation of grids (jobs in telecommunications, data, consultancy, etc.). In total, EY & Eurelectric (2024) estimates that two million additional jobs will be created by 2050. Moreover, these are expected to be quality jobs (U.S. Department of Energy, 2013) and to promote new learning and training opportunities in *skills* needed for related jobs[19].

In terms of the number of salaried employees, there were around 2,500 people in the ACBC in 2021 in the electrical energy, gas, and steam sectors, some of which are in the area of management and operation of electrical grids. In the field of the manufacture of electrical material and equipment and computer and electronic products, there were 16,535 people, in telecommunications and IT, 17,417, in consultancy, 38,946 and in R&D, 8,681[20].

In the ACBC, in 2021, there was a general increase in labour costs per employee[21] (CLA), which stood at 39,204 euros per year for the average of the economy. As can be seen in Graph 5, in the particular case of the activities most closely related to electricity grids (electricity, gas, and steam; manufacture of electrical material and equipment and computer and electronic products), wage levels were 85,488 euros (118.06% above the economy average), 45,604 euros (16.33% higher) and 38,781 euros (1.08% lower) respectively.

[18] For more detail see section 2.3.4 on the impact of network investment on inclusiveness.
[19] For more details see section 2.4.5.
[20] It should be noted that these figures include jobs in IT and electronics companies not directly related to electricity grids.
[21] Estimated as the ratio of total remuneration to the number of employees.

Graph 5 **Labour cost per employee in the ACBC in 2021**



Note: the horizontal line represents the average CLA level of the ACBC economy.
Source: Prepared by the authors based on Eustat (2023c).

Other related activities, such as consulting and technical activities, had an average CLA of 44,842 euros (14.38% higher), research and development 53,196 euros (35.69% higher than average), and computer and telecommunications activities 47,337 euros and 66,596 euros, respectively (20.75% more and 69.87% higher).

2.3.3 Positive environmental and health impacts

Achieving the EU target of reducing GHG emissions by 50-55% by 2030 compared to 1990 levels will have positive environmental impacts on people. Investment in electricity grids will enable the expected reduction in CO_2 and particulate pollutant emissions to be achieved, bringing benefits to people in terms of climate change mitigation, improved air quality, and reduced premature deaths and health costs related to air pollution-related health conditions[22].

In 2022, GHG emissions in the Basque economy amounted to 18,461,387 tonnes of CO_2e, 10.21% below 1990 emissions and 30% lower than the peak in 2002. By activity, the industrial sector has halved emissions compared to the base year (1990), largely due to the substitution of fossil fuels such as coal and oil derivatives by electricity and gas, cogeneration, and

[22] Exposure to high levels of air pollution can cause a variety of adverse health effects, including an increased risk of respiratory infections, heart disease, stroke and lung cancer, which are more common among vulnerable groups (PAHO, n. d.).

investment in energy efficiency. Agriculture, waste management, and energy transformation have also reduced emissions, but to a lesser extent.

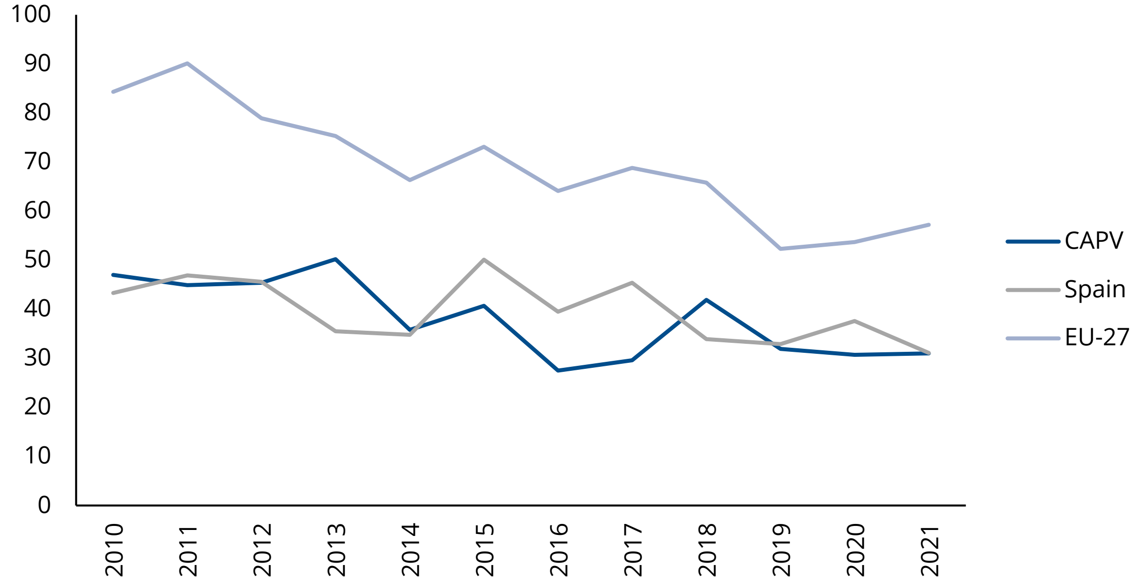
The residential sector has kept them practically stable (Department of Economic Development, Sustainability and Environment, 2024) in a period in which progress has been made in the gasification of household energy consumption (Álvarez Pelegry et al., 2013) and where heat pumps are expected to increase their weight along with other energy self-consumption options and the development of renewables. Meanwhile, the transport and services sectors have more than doubled (231 compared to 100 in the base year) or almost doubled (196.1 compared to 100 in the base year), respectively. In these cases, the penetration of alternative energies will be key, particularly in the case of road transport with the electric vehicle.

Emissions in the ACBC of nitrogen oxides, sulphur dioxide, anthropogenic non-methane volatile organic compounds (NMVOCs), carbon monoxide, and particulate matter (PM_{10}), have been halved since 1990, $PM_{2,5}$ by around a fifth, ammonia by a quarter and methane by a third (Basque Government & Department of Economic Development, Sustainability and Environment, 2022).

The 2030 Air Quality Plan for the ACBC proposes, among other measures to improve air quality, two in which electricity grids are key: (i) moving towards sustainable mobility, reducing the consumption of conventional fuels in transport, encouraging the change to other more efficient fuels and/or through other technologies (e.g., biofuels and renewable electricity), and (ii) advancing in the decarbonisation, denitrification, and desulphurisation of the energy sector, with the specific promotion of renewable technologies and improved energy efficiency (Basque Government & Department of Economic Development, Sustainability and Environment, 2024).

Graph 6 shows the indicator of premature deaths due to air pollution (measured with $PM_{2,5}$) per 100,000 inhabitants. This indicator measures the relationship between health and air quality, and in the case of the ACBC, this figure has had a downward trend, with levels that are also much lower than those of the EU (31 deaths per 100,000 inhabitants in the Basque Country versus 57 deaths in the EU).

Graph 6 Premature deaths due to air pollution ($PM_{2,5}$) (per 100 000 inhabitants)



Source: own elaboration based on data from the European Environment Agency.

In the EU, by 2030, emission reductions are estimated to prevent 58,000 premature deaths and save between 40 and 140 billion euros in health costs related to the impact of poor air quality (European Council, 2020; Deloitte et al. Monitor, 2021).

An additional issue related to the environmental impact of the grids refers to the Community regulation that establishes the transition of electricity grids to equipment free of SF_6 as a dielectric gas. This EU regulation requires manufacturers of medium voltage equipment to develop a new SF_6-free technology. The transformation will take place in stages, depending on the voltage level, with 24 kV equipment being the first to be affected. Subsequently, equipment up to 36 kV will be affected (European Commission, 2020).

This regulation is raising difficulties in interpretation so that each state is adopting its own understanding. Manufacturers can continue to produce the old equipment because part of their sales are made abroad and because, prior to this, the penalties for non-compliance have not yet been developed[23]. However, integrating these SF-free solutions$_6$ has already started in Europe, and 2025 is expected to be a decisive year for their implementation.

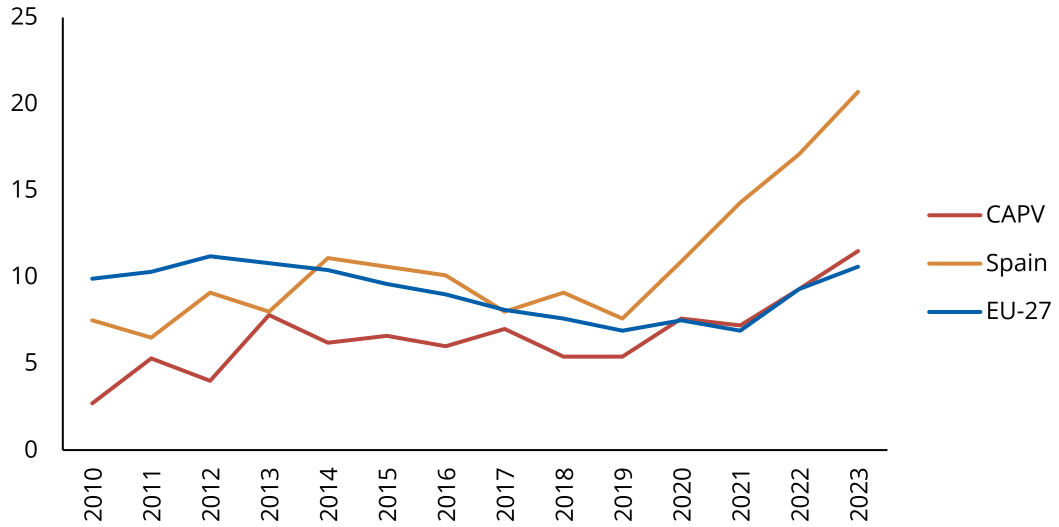
[23] In addition, the penalties would fall, in principle, on those responsible (an undefined term that is generating controversy) and that would mean placing the burden of compliance on the electricity companies that are the owners of the infrastructure and that, in addition, have equipment in *stock,* so that they could in the future be penalised because they replace equipment with other equipment that does not yet comply with the regulations but that complied with them at the time of purchase.

2.3.4 Inclusiveness

As just mentioned, the increased penetration of renewables and improved levels of energy efficiency, made possible by adequate investment in electricity grids, is expected to translate into lower electricity prices for households. Given that one of the determinants of energy poverty[24] in Europe is high energy prices (European Commission, n. d.), a sustainable and just transition[25], including vulnerable groups, can contribute to its mitigation.

In this context, in 2023, 20.7% of the population in Spain could not afford to keep their homes at an adequate temperature during the winter, while this percentage in the ACBC was almost half (11.5%), making it the Autonomous Community with the lowest level of energy poverty measured by this indicator, and with a level similar to that of the EU (see Graph 7). The indicator has been on an upward trend since 2020, reflecting the effect of the pandemic and the energy crisis on households' ability to keep their homes at an adequate temperature.

Graph 7 People who cannot afford to keep the dwelling at an adequate temperature (%)



Source: Prepared by the authors based on data from INE and Eurostat.

[24] A household or individual suffers from fuel poverty if they experience inadequate levels of essential energy services at home, such as heating, cooling, lighting and appliance use (Thomson et al., 2017; Thomson & Bouzarovski, 2020).

[25] "A just transition means greening the economy in a way that is as fair and inclusive as possible for all stakeholders, creating decent work opportunities and leaving no one behind. A just transition involves maximising the social and economic opportunities of climate action, while minimising and carefully managing any challenges, including through effective social dialogue among all affected groups and respect for fundamental principles and labour rights" (ILO, 2021).

Beyond price reductions, increased investment in grids can provide greater possibilities for deploying alternative solutions for organising energy activities. Developing local renewable energy projects that offer opportunities for community participation, generate employment, and promote local economic development can help improve energy access for various disadvantaged groups (e.g., those at risk of poverty, energy poverty, and exclusion).

Indeed, Caramizaru & Uihlein (2020) find that energy communities contribute to the empowerment of their members, promoting social equity and energy justice, where community benefits are maximised, and community participation is increased while marginalised or vulnerable groups are recognised.

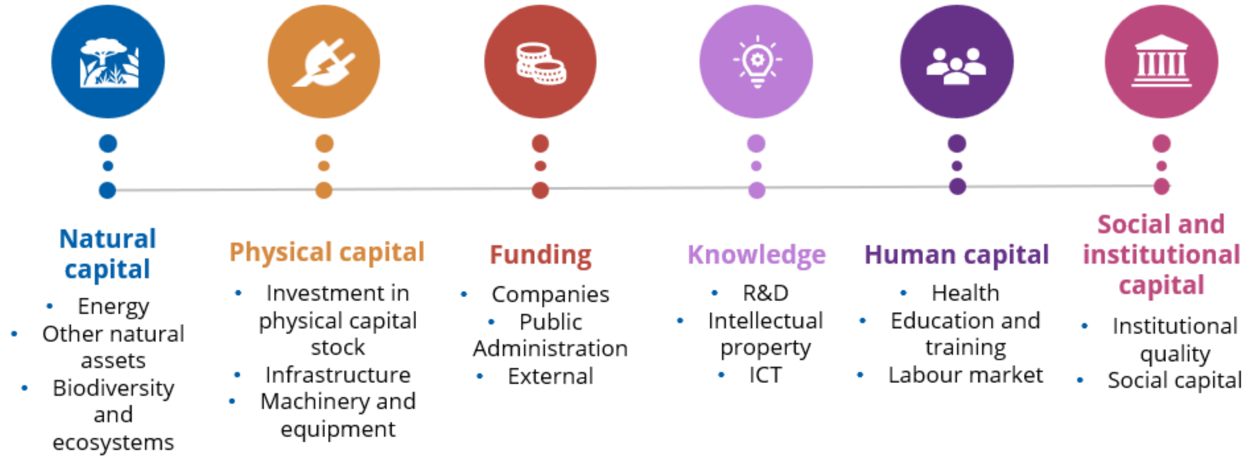
In this way, energy communities and the active participation of consumers in the energy system are expected to foster territorial and social cohesion, where access to clean energy at a lower cost, higher levels of employment and training increase the attractiveness of the counties and provinces of the ACBC, while reducing inequality in the territory (Valero et al., 2024).

In this sense, it is worth highlighting that the ACBC constitutes the central pole of the development of energy communities in Spain, with 31% of the total number of these (118 of the 386 active energy communities in 2023) and around three times more than the following three autonomous communities with the highest number of active energy communities (Catalonia with 43, Valencia with 40 and Navarra with 36) (Valero et al., 2024).

2.4 Dynamic levers

The key elements of each dynamic lever related to electricity grids are presented below for the case of the ACBC.

Figure 4 Dynamic levers of the territorial competitiveness analysis framework



Source: own elaboration based on Orkestra (2021).

As can be seen, some elements of some levers converge in others, so it is necessary to consider possible interactions between them when promoting change.

2.4.1 Natural capital

According to Orkestra (2023), natural capital is the "set of assets related to nature that can generate economic value and well-being for people. Its study is necessary to improve the competitiveness and sustainability of a territory and its companies" by improving efficiency and productivity in the use of natural resources or reducing the environmental footprint. One way of making the most of ACBC's natural resources is by using available energy resources, particularly renewable ones.

In this respect, the electricity capacity in the ACBC in December 2023 would amount to, according to data from Red Eléctrica (2024b), 2,973 MW, with around 581 MW of renewable energy. The energy strategy of the ACBC (Strategy 3E-2030) proposed reaching a renewable electricity capacity of 878 MW in 2025 and 1,440 MW in 2030 (13% and 19% of the electricity supply, respectively) (EVE & Basque Government, 2017).

More recently, the Territorial Sector Plan (PTS) for renewable energies proposed the installation of 2,500 MW of solar photovoltaic, 1,100 MW of onshore wind, and 2,450 MW of other technologies, including biomass, geothermal, aerothermal, solar thermal, oceanic and mini-hydro, which would entail the use of indigenous renewable resources for 27.9% of final energy consumption (the current 10% plus the 17.9% derived from the development of selected location areas (ZLS)). While this would meet the target set out in the 3E-2030 Strategy, it would fall short of the national and European targets of 42.5% renewables by 2030 (European Commission, 2023) and would also make it difficult to achieve carbon neutrality by 2050 (Basque Government, 2023a).

Table 1 shows the potential for the use of renewable energies in the ACBC. As can be seen, it is in solar photovoltaic, wind, biomass, and geothermal energy where the potential for future use is greatest. The potential for ocean energy is medium, and the potential for solar thermal and mini-hydroelectric energy is low.

Table 1 Renewable energy potential (MW)

Origin	Net utilisation potential (MW)	Exploitation potential
Solar photovoltaic	More than 1,000 MW	High
Solar thermal	Between 100 and 500 MW	Under
Wind	More than 1,000 MW	High
Geothermal	Between 500 and 1,000 MW	High
Biomass	More than 1,000 MW	High
Oceanica	Between 100 and 500 MW	Medium
Mini-hydraulics	Less than 100 MW	Under

Source: Basque Government (2023b) in Orkestra (2023).

To fill this gap, building roofs (around 1,600 MW) should be promoted, as well as the development of new citizen-driven proposals for self-consumption (Orkestra, 2023) as energy communities.

Energy dependence on both the rest of the country (especially in electricity supply) and the rest of the world (gas and other fuels) is very high and is not expected to suffer considerable reductions, despite the growing solar energy projects promoted by companies and citizens and the investment of 33 million euros proposed in the Energy Transition and Climate Change Plan 2021-2024 (Initiative 4, solar photovoltaic energy for an electric and renewable future). This is because according to data from Sancho Ávila et al. (n.d.), the ACBC is among the Autonomous Communities (ACs) with the lowest levels of radiation, especially during the months of December to February.

Likewise, the territory's onshore wind potential is lower than that of the rest of the autonomous regions of Spain. According to data from Aymamí et al. (2011), this potential with an average annual speed of more than 6 m/s at a height of 80 m was around 3.9 GW; 2.3 if the minimum average annual speed considered was 6.5 m/s.

As far as hydraulic potential is concerned, there is an important tradition of mini-hydroelectric power plants in the ACBC, with more than 138 MW installed in 2020 in more than a hundred plants (Basque Water Agency, 2020) where the greatest use is to be found in Guipúzcoa. However, no significant developments are expected in this area given that the additional potential is small and, on the contrary, could even decrease in the event of the closure of some facilities.

From summer 2023, the Labraza and Azazeta wind farms in Álava promoted by Haizeindar, the Indarberri (with Solaria) and Ekinea solar plants, and the Petronor synthetic fuels plant in the port of Bilbao, with a process for recovering urban waste (within the framework of the Bilbao Port Decarbonisation Hub project) are planned.

In the framework of the Basque Government's Energy Transition and Climate Change Plan 2021-2024 (Department of Economic Development et al., 2021), the ACBC initiative is to become an international benchmark in ocean energy. Likewise, Initiative Three on the Basque industry at the forefront of wind energy had a budget of 1 million euros in wind, offshore wind, and BIMEP, and Initiative Four on solar energy in the face of an electric and renewable future had a budget of 33.1 million euros.

Because of the energy objectives in the ACBC, important investments are expected in the coming years, especially in renewables, to make the most of the natural resources available in the territory. To achieve this penetration in the electricity system, adequate investment and planning of the electricity grids is necessary (IEA, 2023c), as will be seen in the following lever on physical capital.

This will lead to greater efficiency in using natural resources, developing advanced services around renewables and electricity grids, and promoting more circular business models and value chains.

However, the development of electricity grids and the utilisation of renewable energy resources requires investment in traditional grid infrastructures as well as additional digital equipment, the production of which requires, among other things, critical *raw* materials (*Critical Raw Materials* or CRM). Table 2 provides a non-exhaustive list of raw materials for smart grids.

Table 2 Equipment and CRM associated with smart grids

Raw materials needed	Equipment
Rare earths: dysprosium, hafnium, neodymium, praseodymium, samarium and terbium	Smart meters, permanent magnets
Rare earths: yttrium, cerium, europium, terbium Critical metals: gallium, indium, tellurium	Touchscreens, catalytic converters, alloy additive
Rare earths: erbium, hafnium, neodymium Critical metals: silicon	Sensors, alloys, permanent magnets, fibre optics, lasers
Copper and aluminium	Electrical connections and grids
Gallium	Integrated circuits, LEDs, photovoltaic cells, semiconductors
Gold	Electrical contacts (relays, switches), welding joints, connections
Silicon	Integrated circuits and electronic components in general
Silver	Microelectronic components, solder alloys, electrical contacts, printed circuit boards
Tungsten/Tungsten	Dielectric materials, filaments, resistant metals
Platinum Group Metals (PGMs)	Electronics and electronic equipment

Source: Larrea Basterra (2023).

However, the ACBC does not carry out domestic extraction of metallic minerals (Eustat, 2023a). This means that it must import them or import the finished or semi-finished products that contain them and make progress in terms of the circular economy, which will enable the reuse of the metals contained in products that have reached the end of their useful life.

2.4.2 Physical capital

According to Orkestra (2023), adequate physical capital stocks must be available to drive a comprehensive transformation that will impact the entire economy, facilitating new ways of producing, distributing, and consuming goods and services. If the necessary stock is unavailable, it must be developed. Along these lines, it is important to undertake the necessary investments in physical infrastructures to carry out the energy and digital transition.

Strengthening electricity grids, improving their flexibility, ensuring the quality of supply, and establishing links with other energy sectors such as transport, construction, industry, and hydrogen can support the growth of renewables, including distributed renewables, shaping the energy system of the future (ENTSO-E, 2024). In other words, infrastructure is key to harnessing the ACBC's renewable natural capital. Table 3 gives details of the transport grids in the ACBC.

Table 3 Electricity transmission grids of the ACBC (2023)

Year 2023	Basque Country	Spain	% of total	Map of electricity transmission grids in the ACBC
km 400 kV circuits	699	22.057	3,2	
km 220 kV circuits	662	20.220	3,3	
km circuits <220 kV	0	2.945	0,0	
km circuits	**1.361**	**45.222**	**3,0**	
400 kV positions	90	1.698	5,3	
220 kV Positions	150	3.587	4,2	
Positions <220 kV	0	1.192	0,0	
Positions	**240**	**6.477**	**3,7**	
Transformers * (MVA)	**5.100**	**91.935**	**5,5**	

*Note 1: * = does not include phase shifters.*

Note 2: Includes transmission grid assets of all companies.

Source: Red Eléctrica (2023) y Red Eléctrica (2015).

According to Red Eléctrica & the Spanish Government (2020), it is estimated that 2026 investments in the ACBC will amount to around 120 million euros, of which 71 million will be in the initial grid and the rest in new projects. In April 2024, three modification proposals related to new demands (industrial and data centres[26], among others) were included: (i) in Arrigorriaga (6.5 million euros cost overrun); (ii) Álava (10.4 million euros cost overrun) and (iii) Santurce 220 kV (0 euros cost overrun).

In addition, the interconnection with France at three points (project of common interest in agreement with European Commission (n.d.)), including the interconnection with France via the Bay of Biscay, to be commissioned in 2026-2028, and two reinforcement projects. Map 1 shows more details on interconnection investments and others.

[26] In September 2024, the Spanish government announced that data centre developers (as well as hydrogen projects) will have to bid for access to grid nodes, provided that the applications exceed the capacity of this point of the electricity grid infrastructure. The aim is that, when this happens, projects will compete on their ability to avoid GHG emissions as well as on their socio-economic and territorial impact, as an instrument to address the growing social rejection of the installation of large renewable parks associated with this type of investment (Maria, 2024).

Map 1 Investments in the electricity transmission grid 2021-2026 in the ACBC

Interconnection planning	CAPEX (M€)	OPEX (M€/año)	List of performances	Description
INT_ESP-FRA_1: Spain - France interconnection via the Bay of Biscay	939,6	9,29	Substation extensions, new converter stations, new lines and cables	The project consists of a new submarine interconnection between Spain and France in direct current, with VSC technology and consisting of two symmetrical 400 kV monopoles of 1,000 MW each. This interconnection will connect the existing 400 kV Gatica substation by means of a 400 kV double circuit.
INT_ESP-FRA_2: Reinforcements interconnection Spain - France (Gatica)	11	0,16	Expansion of substations, repowering of lines, new transformers	The project includes internal reinforcements associated with the future submarine interconnection between Spain and France via the Bay of Biscay: - Repowering of the Gatica - Gueñes 400kV, Gatica-Azpeitia 400kV, Gatica - Amorebieta and Amorebieta-Itxaso 400kV lines. - New transformer at Gatica 400/220 kV (>2026).
INT_ESP-FRA 3: Reinforcements interconnection Spain - France (Hernani-Argia)	6,6	-	Driver changes	The project consists of the renovation and replacement of the conductor of the current Hernani - French Border 400 kV section of the Hernani - Argia line.

Planning	CAPEX (M€)	OPEX (M€/year)	List of performances
Action RDP_North: Network of departure Navarra, Basque Country and La Rioja	76 M€	0.99 M€/year	New substations, extension of substations, new lines and cables (Güeñes-Itxaso, Luminabaso, La Serna), repowering of lines and new STATCOMs.
AF_02: Railway axis supply: Burgos-Vitoria	1.1 M€	0.14 M€/year	Substation extensions
APD_PVA: Support to the distribution network in the Basque Country	30.8 M€	0.73 M€/year	New substations, new adaptations to PO, extension of substations, new lines and cables (Abanto, Ali, Barrundia, Elgea).
New Navarra-Basque Country axis: integration of renewables and technical solutions	65.2 M€	0.43 M€/year	Substation extensions, new lines and cables

Note: Red Eléctrica is investing in Dynamic Line Rating (DLR), deploying more than 750 DLR devices to maximise the use of the transmission grid (Smart Grids Info, 2024b)[27].
Source: own elaboration based on Red Eléctrica & Government of Spain (2020).

Although this is something generalised in Spain, in the case of the ACBC, the percentage of denied requests for connection to the distribution grid is very relevant both in generation and industrial consumption and batteries. This means that the grids are already a bottleneck for the decarbonisation of industry in the territory.

In this sense, the grids currently available in the ACBC are those designed under the criteria of the seventies of the last century, only prepared to absorb vegetative growth and not for today's high electrification requirements, both in terms of quantity and power (renewable generation, electrification of consumption and batteries). It should be noted that investment must also be made in making infrastructure resilient to climate change.

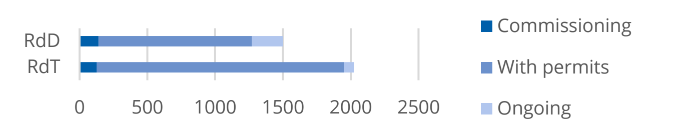
Therefore, measures need to be taken to (i) strengthen connections between transmission and distribution grids, (ii) expand the 132 kV grid and upgrade the existing grid, (iii) develop new transformer stations and substations as well as resize and improve the efficiency of existing ones, (iv) change the layout of lines to avoid flooding areas including elevation and waterproofing of equipment, and (v) promote energy efficiency and the use of higher resistance conductors.

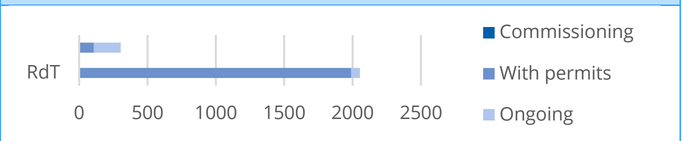
[27] These devices enable the integration of renewable generation and secure electricity supply. "DLR systems consist of sensors and weather stations that capture different parameters of the drivers and environmental conditions in real time, advanced IoT communication systems and artificial intelligence calculation algorithms. This will make it possible to accurately estimate the (dynamic) transport capacity of the lines at any time and optimise their *use*" (Smart Grids Info, 2024b).

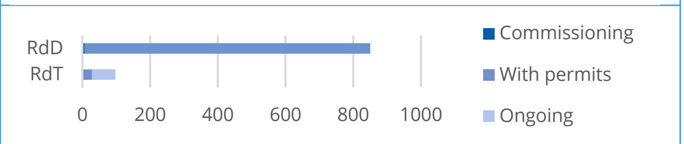
[Table 4](#) presents the data on the access capacity of installations to the electricity grid (both transmission and distribution) for the ACBC as of July 2024. As can be seen, everything in hydro and other technologies is already in service. However, in the rest of the technologies, most applications have permits but have not yet come into operation.

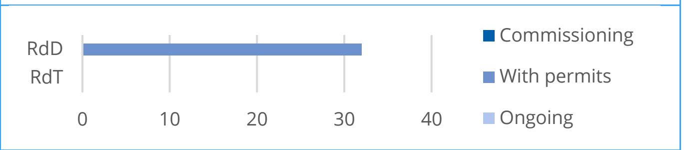
Table 4 Facility access capacity data (MW)

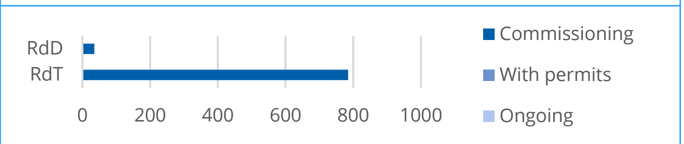
Wind	RdT	RdD
Commissioning	126	140
With permits	1.826	1.131
Ongoing	72	230
Photovoltaics	**RdT**	**RdD**
Commissioning	0	5
With permits	1.990	103
Ongoing	64	196
Batteries	**RdT**	**RdD**
Commissioning	0	6
With permits	29	844
Ongoing	69	0
Hybridisation	**RdT**	**RdD**
Commissioning	0	0
With permits	0	32
Ongoing	0	0
Hydraulics	**RdT**	**RdD**
Commissioning	785	35
With permits	0	0
Ongoing	0	0
Other technologies	**RdT**	**RdD**
Commissioning	1.230	639
With permits	0	21
Ongoing	0	0

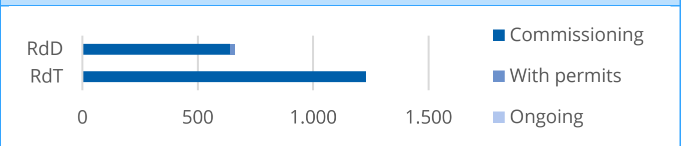








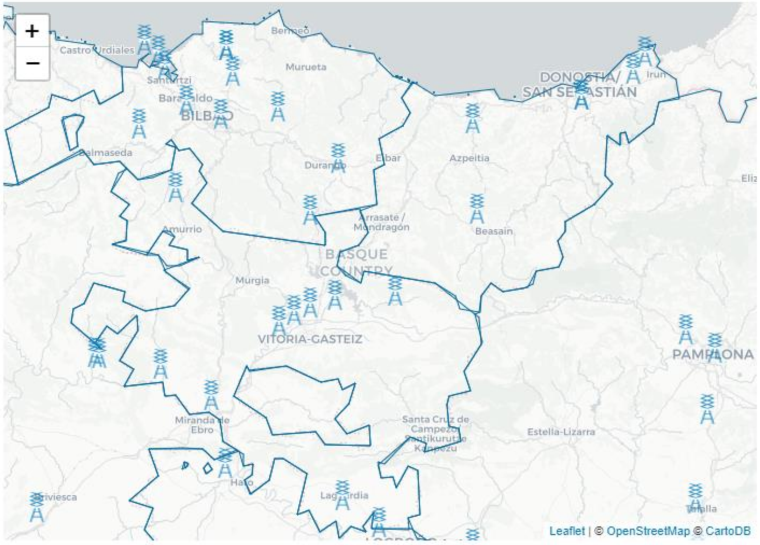




Note: TTR = transmission grid, DTR = distribution grid.
Source: Red Eléctrica (2024c).

Map 2 shows the existing 220 and 400 kV nodes in the ACBC, i.e., those sites where three or more power lines or transformers converge with the same voltage level.

Map 2 220 and 400 kV nodes in the ACBC



Source: Red Eléctrica (2024a).

In terms of smart grids, between 2011 and 2015, the Basque Government, through the Basque Energy Agency and i-DE, developed the Bidelek Sareak project, the aim of which was to provide smart grids in rural and urban areas (Lea Artibai, Portugalete, and Bilbao, among others) to improve the efficiency and security of the electricity supply, enabling a more flexible, robust and secure system to be achieved. As a result, the ACBC has more than 415,000 smart meters, advanced technologies in 2,400 transformation centres, and three electricity substations modernised with digital technology (EVE, n.d.).

In the ACBC, i-DE (Iberdrola Distribución Eléctrica) manages more than 4,430 km of high-voltage lines and more than 18,600 km of low-voltage lines. It also has 11,916 transformation centres in service and 165 substations (El Diario Vasco, 2023). As a result of all these facilities and the regular checks, inspections, and monitoring they carry out, the company maintains a level of service quality in the territory above the national average (El Diario Vasco, 2023). This also enables to improve the safety and quality of the energy supply, operational efficiency, and better integration of the energy sectors, enabling the promotion of new technologies such as electrolysers and heat pumps in the building and industrial sectors.

In addition, investment is needed to ensure the resilience of electricity transmission and distribution infrastructure to climate change. In this respect, electricity grids are a particularly vulnerable infrastructure to climate change, and attention should be paid to them due to the trend towards electrification (Tecnalia et al., 2020). To this end, measures such as (Chatterjee, 2024; IAEA, 2019) (i) changing the layout of lines to avoid flooding areas, including elevation and waterproofing of equipment (transformer stations, substations, etc.); (ii) promoting energy efficiency and the use of higher resistance conductors; and (iii) improving the efficiency of transformer station and substation equipment (transformers, metering equipment, etc.).

"Different studies have estimated the costs of adapting electricity grids to the energy transition at between 38 and 46 billion euros" (Tecnalia et al., 2020).

2.4.3 Funding

This lever includes all the factors that make financing the generation of economic value and well-being possible. It is considered critical to guarantee the appropriate tools and instruments for the financing of investments, which, as has already been indicated, is essential for the transition towards decarbonisation and electricity grids, both in the ACBC (see section 2.4.2) and in the rest of Spain and the world (see sections 3.1 and 3.2).

The activity of electricity grids is regulated, as is their remuneration. With a long tradition and technological maturity, it is *a priori* considered a low-risk investment. However, some difficulties need to be highlighted.

Firstly, although the facilities become operational within one year, it is not until two years later that they begin to receive remuneration for the investment. They are compensated for this delay, but according to Rodriguez (2024), it would be advisable to bring forward the start of payment because of its positive financial repercussions.

Secondly, in recent years, grid companies have been receiving provisional remuneration (in fact, the closure has been pending since 2016), given that there is a delay in the closure of the definitive remuneration by the Ministry for Ecological Transition and the Demographic Challenge (Miteco) due to the complexity of carrying it out.

Regarding the regulatory period, the National Markets and Competition Commission (CNMC) awaits a resolution to establish the 2020 remuneration. This delay creates uncertainty for investors.

The remuneration model applied in Spain is based on a model that recognises investments already made and the weighted average cost of capital[28] (WACC). From 1 January 2020 until 31 December 2025, the WACC for electricity transmission and distribution activity is 5.58%, which does not promote new investments in the territory.

Although there is no discussion on its use as a method, there is discussion on how to construct each parameter that makes it up. In this sense, this remuneration rate is a determining factor in the incentives to invest in grids, and if it is not perceived as sufficient in the new regulatory period (2026-2031), the necessary investments may not be undertaken, even if they are financed.

Thus, the constraint for grid investment is not in the financing capacity of the grid companies but in regulatory limitations, such as the investment cap and the lack of remuneration for early investments. Although it will be detailed in section 3.2, there is a quantitative restriction on the volume of recognised investments because, previously, remuneration was not designed to

[28] In May 2024 the CNMC opened a consultation to receive comments on the calculation of the parameters linked to the WACC.

respond to current challenges and needs, with a growing supply of renewables (some of small size) and electrification of transmission.

On the other hand, in addition to the above drawbacks or requirements, there are other new financing needs related to the need to ensure a reliable energy supply, adapt to grid connections, and address cybersecurity in a context where the expansion of the electricity grid is lagging behind the demand for new connections, which are currently not appropriately addressed by current regulations.

In this situation, where current technology infrastructure and systems are several decades old, are not sufficiently equipped, and where flexibility management is not mature to address future challenges, Accenture & Eurelectric (2024) consider that grid operators should be supported by clear regulations to digitise the construction, operation, and maintenance of the electricity grid. Indeed, regulators must be able to promote investment in digitisation and ensure adequate compensation.

This digitisation also faces the problem that, in many cases, the technologies are not sufficiently mature, which adds uncertainty about their future viability and hinders the ability to obtain financing. However, adequate investment in grids and their digitisation could avoid investments in assets such as generation.

There are three main axes from which the funding lever can be analysed: public administration, companies, and the outside world (Orkestra, 2021). The three axes are analysed below.

On the side of the Public Administration, according to P. Chaves et al. (2021), the regulatory framework should offer financing instruments with special emphasis on regulated sectors. Along these lines, new approaches to regulatory innovation are proposed[29] , including pilot projects such as Bidelek Sareak[30] with Iberdrola.

The Basque Government also cooperates with companies on projects of special interest. In this sense, the collaboration with Iberdrola Spain to improve the power lines and protect certain areas of the Urdaibai can be cited (Iberdrola Spain, 2023). To this end, the Department of Economic Development, Sustainability and Environment has allocated 352,810 euros to modernise and digitise the electricity grid through the signing of an agreement (signed in November 2023) with i-DE, Iberdrola España's distributor, for four years and within the framework of the Recovery, Transformation and Resilience Plan, financed by Next Generation EU.

Since the 1980s, the Basque Government has created institutions and designed support programmes and instruments to help industrial companies, particularly small and medium-sized enterprises (SMEs), overcome economic and business challenges. These institutions include the Basque Business Development Agency (SPRI), the Basque Finance Institute (IVF), the company Gestión de Capital Riesgo de Euskadi, the Basque Trade and Investment Agency, and the Elkargi Reciprocal Guarantee Society (Fernández Gómez & Larrea Basterra, 2021, 2022a).

[29] For more details see section 2.4.6.
[30] For more details see section 2.4.2.

The most common support instruments include loans, loan guarantees and equity investments. Likewise, repayable cash advances and interest subsidies are also offered. The ACBC has programmes such as Gauzatu Industria, Indartu, Reindus, Renove Industry 4.0, Renove Industrial Machinery, Hazitek, Elkartek, Hazinnova or Bind 4.0. It also offers financial support through funds dedicated to various policies (e.g., Finkatuz Fund[31]). In 2024, it has, among others, a programme for industrial cybersecurity, another for professional digital skills, and MOVES III[32] and T Energética, which include a section for the development of recharging infrastructure (Department of Industry, Energy Transition and Sustainability, 2024).

In addition, venture capital management provides funds for venture capital initiatives and assists in managing companies, developing strategic plans, etc. SMEs are also offered bank loans to finance working capital, lines of credit, and advances for R&D programmes with external funds or financial and technical guarantees (Fernández Gómez & Larrea Basterra, 2022a). The Sociedad de Capital Desarrollo de Euskadi SOCADE, S.A. seeks to invest in tractor companies that want to expand through innovation and internationalisation, its investment strategy being aligned with the smart specialisation strategy defined by the Basque Government (Department of Treasury and Finance, 2022a).

In addition, the Basque Energy Agency (EVE) plays an important role in financing green and sustainable investments and projects in the energy field and has participated, among others, in the aforementioned Bidelek Sareak electricity grid project. EVE supports the development of new infrastructure projects and the creation of companies specialising in new technologies through capital investments and subsidies (i.e., in energy efficiency, renewables, and sustainable mobility). It is also involved in promoting R&D in energy (e.g., by participating in renewable energy demonstration projects), among others (Fernández Gómez & Larrea Basterra, 2021, 2022a).

Also, the Basque Government has played a key role in developing a sustainable bond market since 2018. These issues are part of a strategy to create a green finance ecosystem to help address the environmental, economic and social challenges of the territory (Fernández Gómez & Larrea Basterra, 2021, 2022a).

The ACBC also has a Management and Finance Forum, an association for exchanging knowledge and experience in business management, obtaining advantages, organising and coordinating activities to broaden professional knowledge, producing information, and strengthening relations between participants (Management and Finance Forum, 2024) one of whose members is Arteche.

Companies and actors involved in electricity grids can also access European funding. In this sense, the distribution of EU grid funding at the regional level roughly matches the distribution of shares, but this is not always the case (Vasiljevska et al., 2021). Regarding EU funds raised,

[31] The Finkatuz Fund, which is managed by the Basque Finance Institute, invests in strategic sectors considered preferential, including energy, electronic and information technologies (Governing Council, 2023). However, in spring 2024, this fund had around two thirds of its budget unspent (Pereda, 2024b).

[32] This programme belongs to the Spanish Government but is managed by the Autonomous Communities.

the Community of Madrid (with 79.1 million euros) and the ACBC (with 78.1 million euros), are among the five regions that have received the highest volume of EU funding. In the case of Madrid, the main destination was demand management; in the case of the ACBC, it was smart cities.

According to P. Chaves et al. (2021), the regulatory framework must offer financing instruments with special emphasis on regulated sectors. In this line, new approaches to regulatory innovation are proposed to experiment where the variables where innovation takes place and the agents involved are combined. Among these regulatory innovation approaches, four possibilities can be highlighted[33]: (i) initiatives for the deployment of technologies, (ii) pilot projects (such as Bidelek Sareak[34]), (iii) regulatory pilot projects, and (iv) regulatory *sandbox* projects.

However, according to Orkestra (2023), the public sector cannot lead the way towards developing a green finance ecosystem. Its mission should be to develop instruments that incentivise investment for decarbonisation in general and electricity grids in particular, which should be done according to the recommendations in Figure 5.

[33] For more details see section 2.4.6.
[34] For more details see section 2.4.2.

Figure 5 **Recommendations for the design, implementation, monitoring and evaluation of incentives for clean technology investment**

Who receives?	• Incentives should be targeted at persons or entities that are **affected** by market distortions that prevent them from making the necessary investment decisions.
Who grants?	• There is a wide variety of programmes and institutions that grant investment incentives within a territory. Thus, those granting incentives must be **coordinated** with each other in order to optimise the use of funds.
When is it received?	• The incentive needs to come at the **right time**, be of a **duration** that allows the necessary investments to be made over time and also be **sustainable** in the long term.
What or how much is received?	• The amount of incentives is relevant as large volumes of investment are required, but it is important to **avoid a race or war of incentives** that could be detrimental to all countries (to a greater or lesser extent).
Why are they received?	• When applying for incentives, there is a whole set of requirements that must be met. These requirements **should not become obstacles** for actors without adequate resources to apply.
How are they implemented and monitored?	• Once the incentives reach their recipients, the entities that provide them need to **follow up** to ensure their correct use, implementation and effectiveness.
How are they assessed?	• It is advisable to have a **body to assure** taxpayers that the processes for designing, granting, monitoring and evaluating incentives are rigorous. • There is a need to **assess the impact** of the incentive programmes being developed, **beyond their environmental objectives**.

Source: Larrea Basterra & Mosquera López (2024).

This requires the participation and leadership of private financial institutions (i.e., banks, investors, alternative financing, insurance companies, consultancies, rating agencies, etc.) as well as other in-house and external sources.

Although the financial ecosystem of the ACBC had a strong impact on the Basque economy in the past, its presence has been falling over the last three decades as a result of the concentration in financial centres in Europe or the relocation of banking centres in Spain (i.e., BBVA) or the sale of industrial holdings of financial institutions required by the European Central Bank (Orkestra, 2023).

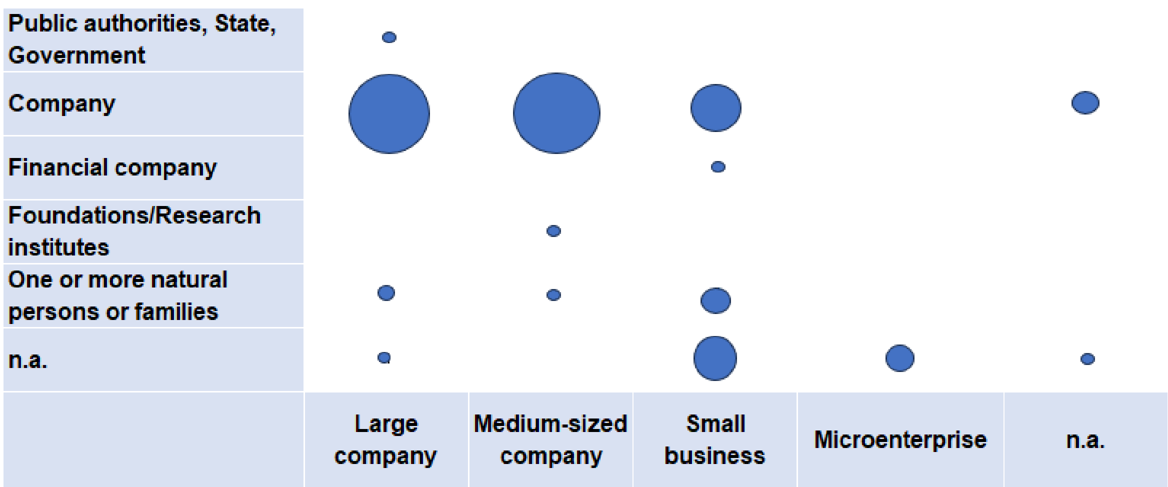
Companies in the ACBC that are related to electricity grids are looking for ways to finance their activities from other sources. The differences in the size of the agents influence their capacity to obtain it. Thus, a large company such as Iberdrola (i-DE's parent company) bases its financial model on financing the group from the holding company through operations with the unconditional and irrevocable guarantee of Iberdrola S.A. (Iberdrola, 2024b). Along these lines, Iberdrola has extensive experience in issuing green bonds, which have been issued since 2014 (Fernández Gómez & Larrea Basterra, 2022a).

It also obtains financing from other international sources, such as the European Investment Bank (EIB), for expanding electricity grids in Spain. In this regard, a recent loan for a project with a total investment of 1,440 million euros, with the EIB contributing 700 million and the company providing the rest. This project aims to increase the efficiency and resilience of the electricity distribution grid, facilitate connection, new electrification uses (e.g., heat pump or electric mobility), and integrate more renewable energy sources into the grid (Iberdrola, 2024c).

Its shares, through Avangrid, are listed on the New York Stock Exchange, and its subsidiary Neonergía is listed on the Brazilian Stock Exchange. Its shares are also included in more than 65 international indices, such as the Dow Jones, EuroStoxx 50, and the Dow Jones Sustainability Index (Iberdrola, 2024a).

However, not all companies related to electricity grids have the same capacity to access certain sources of financing. In the case of the ACBC, most of the companies in the Energy Cluster that are related to electricity grids belong to other business groups. However, there are also seven companies whose shareholders (according to SABI) are individuals or family groups, so there is greater difficulty in accessing financing, which means that the size of the company is smaller. Furthermore, while a large group of these companies can be categorised as large (16 out of 59), 39 are micro, small, and medium-sized enterprises.

Figure 6 Nature of firm ownership vs. firm size



Note: n.a. = not available.
Source: own elaboration based on SABI.

Aggregated data for most companies that are part of the Smart Grids Basque Country Energy Cluster initiative[35] is presented below[36]. The following table shows the volumes of financial investments of the same set of companies (which mainly capture the shareholdings of local companies), both in the long and short term. Long-term investments are more substantial, reaching almost 2,800 million euros, representing around 3.2% of the GDP of the ACBC. In total, both long-term and short-term investments amount to 3,367 million euros.

Table 5 Short and long-term financial investments in millions of euros according to the Smart Grids Basque Country activity classification (2022)

Activity	Long-term investments in group and associated companies	Long-term financial investments	Short-term investments in group and associated companies	Short-term financial investments
Grid operators	2,58	340,61	10,37	313,8
Design, engineering and consultancy services	160,66	14,83	8,78	5,18
Installation, maintenance and customer service	14,7	2,16	27,54	3,06
Data analysis and management	1.653,8	198,03	132,88	4,64
Consumer-oriented services and new user involvement	1.572,02	196,62	133,95	3,43
Advanced high and medium voltage grid equipment and digital solutions	82,82	1,06	35,67	0,03
Power electronics and storage	22,98	0,78	14,22	0,39
Smart meters and metering equipment	340,12	10,15	41,51	2,15
Testing and certification	0	0,05	0	0
Totals	2.202,57	566,56	269,59	328,01

Note: All companies classified in each activity of the value chain according to the Smart Grids Basque Country Energy Cluster initiative have been included in the calculations for each indicator. As a result, there are cases where a company appears in more than one activity. In such cases, the entire indicator has been included due to a lack of detailed information on the weight of each activity in the company's operation, resulting in duplicate companies. However, the totals were calculated by considering each company only once, so the sum by activity may not coincide with the sum by columns.
Source: own elaboration based on SABI.

[35] Most of the companies taking part in this initiative are based in the ACBC, with a special concentration of companies in Vizcaya (see section 3.3.1). However, for this analysis, all of them are taken together, although they may have their headquarters in another Spanish province, as the aim is to evaluate the whole.
[36] The data used are from the SABI database.

Companies in data management, data analytics, and ICT are making the largest volumes of investment (1,989 million euros), followed by design, engineering, and consulting services (1,906 million euros) and grid operators (667 million euros).

The financial leverage[37] for all companies is high at 86.32 (estimated from SABI data)[38]. By business area, grid operators, installation, maintenance, and after-sales services, advanced digital equipment for protection, automation, control, and communication in high and medium voltage, power electronics and storage, and smart meters and metering equipment are above 100, at 125, 164, 145, 115 and 152 respectively.

Table 6 Average financial leverage ratio by branch of activity related to electricity grids according to the Smart Grids Basque Country classification (2022)

Activity	Average Leverage Ratio (%)
Grid operators	124,99
Design, engineering and consultancy services	9,44
Installation, maintenance and customer service	163,55
Data analysis and management	76,85
Consumer-oriented services and new user involvement	50,15
Advanced high and medium voltage grid equipment and digital solutions	144,95
Power electronics and storage	114,50
Smart meters and metering equipment	152,09
Testing and certification	4,77
Totals	

Note: All companies classified in each activity of the value chain according to the Smart Grids Basque Country Energy Cluster initiative have been included in the calculations for each indicator. As a result, there are cases where a company appears in more than one activity. In such cases, the entire indicator has been included due to a lack of detailed information on the weight of each activity in the company's operation, resulting in duplicate companies. However, the totals were calculated by considering each company only once, so the sum by activity may not coincide with the sum by columns.
Source: own elaboration based on SABI.

These figures, some of which are relatively high and may be an element influencing the decision-making of potential investors, are due to the leverage levels of a small group of companies, which are distributed across the different areas of activity.

[37] Dear as: $\frac{Fixed\ liabilities + financial\ debt}{Equity}$

[38] Generally, leverage below 25% is low, optimal between 25% and 50%, and high leverage above 50% (IG, n.d.).

Net worth and financial assets are key indicators. The total asset data for grid operators is particularly high compared to the rest because this activity is not exclusive to the ACBC. A higher level of net assets is evident in grid operators, design, engineering, and consultancy services, as well as the supply of data managers, data analysis, and ICTs. Installation, maintenance, and after-sales services occupy the next position.

Table 7 Total financial investments, total assets, and net worth (millions of euros) of the activities associated with electricity grids according to the Smart Grids Basque Country classification (2022)

Activity	Short and long-term financial investments	Total Assets	Net worth
Grid operators	654,40	24.775,33	9.341,17
Design, engineering and consultancy services	20,00	784,51	4.731,99
Installation, maintenance and customer service	5,21	1.646,17	985,66
Data analysis and management	202,68	4.802,55	1.917,70
Consumer-oriented services and new user involvement	200,05	3.822,32	847,48
Advanced high and medium voltage grid equipment and digital solutions	1,08	1.056,72	151,05
Power electronics and storage	1,17	203,72	39,00
Smart meters and metering equipment	12,30	1.068,28	466,71
Testing and certification	0,06	38,62	12,10
Totals	894,57	33.449,97	16.627,28

Note: All companies classified in each activity of the value chain according to the Smart Grids Basque Country Energy Cluster initiative have been included in the calculations for each indicator. As a result, there are cases where a company appears in more than one activity. In such cases, the entire indicator has been included due to a lack of detailed information on the weight of each activity in the company's operation, resulting in duplicate companies. However, the totals were calculated by considering each company only once, so the sum by activity may not coincide with the sum by columns.
Source: own elaboration based on SABI.

Overall, companies start from a favourable overall situation, which makes them attractive for attracting foreign investment. Not only can the economic-financial position of the company attract such investment, but the context described above may also appear favourable for it (innovation, human capital, etc.). As a result, attracting investment can be done in two ways: via acquisition of a local company or direct investment.

However, in this area, additional efforts can be made to attract foreign investment, considering the current financing needs and the future potential in terms of activity in this sector.

2.4.4 Knowledge

The knowledge lever brings together those intangible assets based on knowledge and ICTs that contribute to economic value and well-being. According to Orkestra (2021), this lever analyses issues related to R&D, intellectual property, and ICTs, which impact improving competitiveness and well-being results and are usually closely linked to innovation[39]. Indeed, in addition to developing new infrastructures, it is necessary to facilitate investments in knowledge of electricity grids to accelerate the transition towards environmentally sustainable competitiveness.

According to Norouzi et al. (2023), smart grids can be viewed from both a transformational and an innovation systems perspective due to their potentially disruptive nature. Indeed, coping with a bi-directional energy flow requires including other concepts, such as flexibility in the power system to address balancing issues. This flexibility, in turn, can be achieved through different technologies (many under development and testing), such as storage devices or vehicle-to-grid systems. For all of these reasons, information technologies, control strategies, and energy management systems are a key element in the design of smart grids.

The move towards smart grids requires digital technologies, which can help solve current operational challenges and support the integration of renewable and distributed energy resources, optimising system efficiency and increasing the speed of transformation. This digital grid transformation will facilitate the deployment of simulation tools, such as digital twins. AI will be used to optimise energy systems, including maintenance. Meanwhile, cybersecurity is becoming an increasingly essential requirement to ensure the security of the energy system (ENTSO-E, 2024).

IEA (2024a) notes that Europe has emerged as a centre of specialisation in smart grid technology, according to the Revealed Technology Advantage (RTA) index. In contrast, Japan, the United States, and China have lower RTA indices, suggesting a clear lack of specialisation in this area of innovation. The ACBC, through its technological strategy Energibasque, seeks specialisation in certain energy areas, including electricity grids. In this sense, it can be pointed out that in 2021, 45% of R&D expenditure was directed towards industrial production and technology and 12.8% towards energy (Orkestra, 2023).

The generation and implementation of new knowledge are key to guaranteeing the competitiveness of the ACBC. Still, it is also essential that this knowledge is oriented towards the needs of decarbonisation (Orkestra, 2023), where electricity grids, as has already been mentioned, can play an important role.

In Table 8, it can be observed that activity 02 Manufacture of computer, electronic and optical products is of a high technological level and activity 06 Manufacture of electrical material and equipment, manufacture of machinery and equipment, manufacture of vehicles of a medium-high technological level. In this sense, the weight of the activity of Manufacture of electrical material and equipment, manufacture of machinery and equipment, manufacture of vehicles stands out, which in the period consulted accounted for almost 22% of all personnel employed

[39] More detail on smart grid innovation can be found in section 2.2.4.

in the industry. Given that activities with a medium-high technological level accounted for around 27%, it can be concluded that these medium-high technological level products are relevant. The manufacture of computer, electronic and optical products (categorised as high-tech) accounted for around 3.4%, which is also a considerable figure considering that this activity has a high technological content.

The results are quite similar for the case of gross value added (GVA) at factor prices, where the GVA of activity 02 accounted for around half of the activities with a high technological content and a large part of the GVA of the activities with a medium-high technological content is from activity 06.

Table 8 Percentage of employed personnel, GVA, and net sales by technology content of the activities of Manufacture of computer, electronic and optical products (02) and Manufacture of electrical equipment and apparatus, manufacture of machinery and equipment, manufacture of vehicles (06)

	2017	2018	2019	2020	2021	2022
Staff employed (number)						
High Technological Level	4,8%	4,9%	5,0%	5,0%	5,0%	5,2%
02 Manufacture of computer, electronic and optical products	3,2%	3,3%	3,4%	3,3%	3,4%	3,5%
Technological Level Medium High	26,2%	26,9%	27,0%	27,0%	27,1%	27,2%
06 Manufacture of electrical material and equipment, manufacture of machinery and equipment, manufacture of vehicles	21,2%	21,7%	21,7%	21,6%	21,7%	21,7%
Gross Value Added at factor cost						
High Technological Level	5,1%	4,8%	5,7%	5,6%	5,3%	5,2%
02 Manufacture of computer, electronic and optical products	2,4%	2,4%	2,6%	2,5%	2,5%	2,5%
Technological Level Medium High	26,4%	26,5%	26,2%	28,1%	27,4%	25,2%
06 Manufacture of electrical material and equipment, manufacture of machinery and equipment, manufacture of vehicles	20,9%	20,4%	20,2%	21,2%	20,5%	18,9%
Net sales						
High Technological Level	4,2%	4,0%	4,6%	4,2%	3,7%	3,4%
02 Manufacture of computer, electronic and optical products	1,7%	1,8%	1,9%	1,9%	1,7%	1,6%

Technological Level Medium High	26,3%	26,0%	26,9%	29,3%	27,6%	24,9%
06 Manufacture of electrical material and equipment, manufacture of machinery and equipment, manufacture of vehicles	21,5%	20,8%	21,4%	23,0%	21,4%	19,4%

Source: Prepared by the authors based on Eustat (n.a.).

Know-how in the value chain of smart grids, grid equipment, storage, and renewable energy needs to be strengthened. From the conception of a product or service, until it is commercially viable, it goes through a series of stages whose progress is measured by technology maturity levels (TRLs), which have a scale between one and nine, from basic research to commercial launch (FutuRed, 2015).

To create new products and services, it is essential to have a grid of laboratories. Spain has a long tradition of researching all links of the electricity grid production chain (from universities, technology centres, equipment manufacturers, and the electricity companies themselves). It has numerous R&D centres, laboratories, and testing and certification facilities (FutuRed, 2015). The ACBC is no stranger to this, as can be seen in Map 3 and in the world map of urban centres of innovation in smart grids (2000-2022) of the IEA (2024a).

Map 3 List of R&D capacities in the ACBC related to electricity grids

Source: Prepared by the authors on the basis of Energy Cluster (2023), FutuRed (2015).

Likewise, as mentioned, the ACBC has an Energy Cluster where companies from different links in the value chain of electricity grids collaborate[40]. Furthermore, different types of research projects are being carried out in the ACBC, such as LIFE IP Urban Klima 2050, developed by Tecnalia in collaboration with the School of Engineering (Tecnun) of the University of Navarra to assess the impact of climate change on electricity distribution grids in Zarautz and Bilbao (Smart Grids Info, 2024a). In fact, numerous R&D projects have been developed in recent years in the field of electricity grids, especially around digital technologies. Many collaborate with companies and research centres and are usually subsidised by the Basque Government (Elkartek, Hazitek) and European (H2020, Horizon Europe) programmes.

Collaboration with industry provides an avenue for technology transfer and commercialisation that will directly impact competitiveness and economic growth (Daniel et al., 2024). Indeed, partnering with equipment and instrumentation suppliers is key to closer integration. As an example, Iberdrola has developed the Global Smartgrid Innovation Hub, located in Bilbao, a global centre of innovation and knowledge in smart grids to help respond to the challenges of the energy transition (El Diario Vasco, 2023). This centre promotes innovation and develops talent[41] through collaboration with universities. It offers opportunities to students and prepares the professionals of the future. More than 200 professionals specialised in related R&D&I participated in the activities that were developed.

Likewise, in the ACBC, the Basque Government collaborates with the Basque Government to carry out R&D activities related to energy within the framework of the Science, Technology and Innovation Plan (Plan de Ciencia, Tecnología e Innovación, PCTI)[42]. The PCTI is based on three main pillars. The first is scientific excellence, which seeks to promote excellent research as a basis for creating and disseminating new knowledge, capabilities, technologies, and solutions. The second pillar is technological and industrial leadership, which seeks to promote strategic projects and strengthen national and international investment attraction. The third pillar is open innovation, aimed at SMEs and seeking, among other things, collaboration with other regions and international innovation ecosystems.

The PCTI aims to boost R&D&I activity in a set of digital, virtual, physical, biological, chemical, and materials technologies with the potential to contribute to specialisation and adaptation to the three transitions[43]. These technologies, related to electricity grids, mainly include (Basque Government, 2023b): (i) artificial intelligence and big data, data science (predictive algorithms, data analytics, digital twins, etc.), (ii) the Internet of Things (IoT) and 5G technologies (IoT connectivity, digital platforms, cloud computing), (iii) cybersecurity (blockchain, productivity or

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[40] See sections 2.4.6. and 3.3. for more details.
[41] See section 2.4.5 for more details.
[42] Annex 3 of the STIP identifies the sectors linked to the RIS3 areas. In this regard, it should be noted that the sectors identified in this report related to electricity networks do not necessarily coincide with those of the PCTI, since the PCTI includes energy in general and not electricity networks in particular. This study has not included metallurgy or the manufacture of metal products, machinery and equipment. On the other hand, the manufacture of computer, electronic and optical products has been included.
[43] In particular, electricity grids straddle two of the three transitions to be addressed, the energy-climate and the technology-digital transitions.

grid cybersecurity), (iv) cyber-physical systems (control algorithms, actuators, embedded electronics, sensors and biosensors), (v) materials and processes, (vi) energy storage and (vii) power electronics.

In the field of publications, the ACBC has a considerable specialisation (above the European average) in publications related to Sustainable Development Goals (SDGs) 7 (Affordable and clean energy) and 11 (Sustainable cities and communities). In 2022, 5.2% of publications were related to SDG 7, compared to 3.8% in 2004 (Orkestra, 2023).

Analysing patents from the European Patent Office (EPO), it can be seen that Basque environmental technology patents accounted for 11% of the total number of environmental patents in Spain, with the data for the ACBC having improved since the beginning of the century. The data for the ACBC show that, in 2020, environmental technologies accounted for 16.4% of patents in the ACBC, with those related to climate change mitigation technologies related to energy generation, transmission, and distribution accounting for 9.4% and those related to climate change mitigation technologies in ICTs accounting for 0.2%.

Table 9 Percentage of patents over the total for the Basque Country (three-year average)

Technology group	2004	2007	2010	2013	2016	2019	2020
2. Climate change mitigation technologies related to power generation, transmission and distribution	1,2	6,6	8,6	9,1	8,1	7,7	9,4
8. Climate change mitigation technologies in ICTs	0	0	0	0,2	0	0,2	0,2

Source: extracted from Orkestra (2023).

However, it should be noted that against this background, electricity grids and their development are highly dependent on geographical location, as each territory/market has its own peculiarities. This limits the innovations that can be implemented, accompanied by legislative constraints/obligations. For this reason, manufacturers must adapt their products and innovation to each market/territory, which is at a different stage of development and has specific regulations.

On the other hand, the development of distribution grids will also foster innovation in decarbonisation solutions for industry, especially through the electrification of industrial processes, either directly or indirectly (e.g., the development of new value chains such as green hydrogen produced from renewable energies, or the use of heat pumps in low and medium temperature processes [food, pulp, and paper, etc.]).

In January 2024, the Basque Industrial Hub for Circularity (BIH4C) was created, an innovation hub for the decarbonisation of Basque industry, led by Tecnalia, driven by the Energy Cluster and made up of the companies Calcinor, Sidenor, SBS Process, Lointek, Petronor Innovación, Smurfit Kappa, Nortegas, and the Consorcio de Aguas Bilbao Bizkaia. It is part of the European

IS2H4C project subsidised by the European Commission through the Horizon Europe Programme. In addition to the 10 Basque companies mentioned above, another 20 European companies are participating in the European project, organised in three other hubs located in Holland, Germany, and Turkey. The hub seeks to exploit the synergies between the different industrial sectors to develop and implement innovative decarbonisation technologies. Furthermore, the *hub* is part of the Net-Zero Basque Industrial Supercluster (NZBISC) initiative (Energy Cluster, 2024).

The companies that make up the hub belong to the oil refining, steel, pulp and paper, and lime sectors, which in the period 2020-2022 reported between 9 and 17% of establishments[44] innovators[45] (see Table 10), while the industry total was 25.1%. On the other hand, the computer and electronic equipment and electrical material and equipment sector reported 48.4% of innovative establishments, well above the value for the entire Basque industrial sector. In addition, telecommunications and R&D and consultancy services relevant to developing smart grids also reported percentages of innovative establishments higher than the average for the total services sector.

Table 10 Innovation in establishments in the ACBC by branch of activity (2020-2022)

Sector	Innovative establishments (%)
Total industry	**25,1**
Extractive, coking and refining industries	9,4
Wood, paper and graphic arts	12,0
Metallurgy and metal products	17,0
Computer and electronic products. Electrical material and equipment	48,4
Total services	**25,1**
Telecommunications, IT and media	42,7
R&D, consultancy and other professional and technical activities	29,2

Note: Unit is the percentage of establishments.

Source: Eustat.

2.4.5 Human capital

Human capital lever refers to a set of dimensions related to people (knowledge, skills, health, and participation) that determine their ability to contribute and participate in the labour market and influence the generation of economic value and well-being (Orkestra, 2021).

[44] According to Eustat (n.d.-a) an establishment is "a unit producing goods or services, which carries out one or more activities of an economic or social nature, under the responsibility of an owner or company, in a place, premises or set of related premises located in a specific topographical location".
[45] The Innovation Survey estimates that an establishment is innovative on the basis of the new version of the Oslo Manual 2018 (Eustat, n. f.-b).

There is a connection between this lever and several of the dimensions included in the framework as well-being outcomes, and it is not always easy to distinguish between the two. Indeed, by way of example, the same element, such as a good level of education, can help people's well-being and, in parallel, contribute to generating economic value.

In a broad sense, all employment generated mainly by investments associated with the deployment of renewables, distribution and transmission grids, sustainable mobility, and the promotion of energy saving and efficiency, grid technicians, computer programmers, and computer systems operations technicians can be identified as green and related to electricity grids (Fundación Biodiversidad et al., 2023).

To carry out these activities, developing capacities or skills in value chains with a broad scope for sustainable transition (renewable energies, digitalisation and communications, grid technologies, optimisation solutions, etc.) is essential. It is necessary to incorporate those capacities that enable the appropriate performance of work processes, particularly green jobs (Orkestra, 2023). Likewise, green jobs generally require skills in the field of digitalisation, so digital skills are a cross-cutting element. Examples include skills such as developing computer systems or architectures integrating hardware, software, and grids (Fundación Biodiversidad et al., 2023).

Table 11 lists the main competencies associated with relevant occupations in the sectors mentioned above, which are related to electricity grids[46]. The occupations (whose codes come from the National Classification of Occupations (CNO)) show the relevance of occupations where university education is required (the CNO code starts with a 2), as well as higher vocational training (the CNO starts with a 3). In this selection, there is a lower presence of occupations related to intermediate vocational training and baccalaureate (CNO code begins with 4 to 8).

As can be seen, the essential knowledge and skills (there are other optional ones) required for the performance of these occupations are varied. In any case, the weight and relevance of the science, technology, engineering and mathematics (STEM) branches of knowledge in this field can be sensed.

[46] To obtain this information, based on the CNAE codes of activities related to electricity networks, the main associated occupations were extracted from the Lanbide graduate survey. With the codes of the occupations, the skills were extracted from the ESCO database. With this horizontal information on *skills,* a platform could be created so that Universities, Vocational Training Centres and others in the ACBC would know the knowledge and skills that they should transmit to their students for their training and retraining.

Table 11 Main essential knowledge and skills for the exercise of occupations related to electricity grids

Activity code CNAE	Main occupations of recent graduates	National Classification of Occupations Code	Main knowledge and skills essential for the exercise of occupations
26. Manufacture of computer, electronic and optical products	Electronics technicians (except electro-medical)	3124	Knowledge: integrated circuits, microelectronics, electronics, lighting components, microassembly, semiconductors Skills: examining semiconductor components, controlling machine operations, recording circuit design on wafers, interpreting assembly drawings
	Electronics engineers	2442	Knowledge: test procedures for electronic systems and products, battery management systems, principles of electricity, types of electronics, environmental legislation Competences: design electrical systems, modify technical drawings, develop electronic test procedures, use technical drawing software
	Assemblers of electrical and electronic equipment	8202	Knowledge: safety engineering, quality standards, electronics, computer equipment, mechatronics Competences: apply welding techniques, apply assembly techniques, control machine operations, interpret assembly drawings, solve operational problems
27. Manufacture of electrical material and equipment	Setters and machine tool operators	7323	Knowledge: types of metal, mechanics Skills: providing suitable tools for machines, solving operational problems
	Assemblers of electrical and electronic equipment	8202	Knowledge: safety engineering, quality standards, electronics, computer equipment, mechatronics Competences: apply welding techniques, apply assembly techniques, control machine operations, interpret assembly drawings, solve operational problems
	Electrical technicians	3123	Competences: monitoring technology developments used in the design, assessing energy needs, and controlling the design quality during activity.
35. Electricity, gas, steam and air-conditioning supply	Industrial and production engineers	2431	Knowledge: engineering principles, project drawings, mathematics, technical drawing, physics Skills: managing research data, performing data analysis, developing open-source software, recording test results

	Electrical engineers	2441	Expertise: solar energy, wind energy, geothermal energy, electrical engineering, technical drawing, process engineering Skills: promoting sustainable energy use, providing information on geothermal heat pumps, ensuring compliance with safety legislation, developing thermal management, modifying technical designs
61. Telecommunications	Telecommunications engineers	2443	Knowledge: system development life cycle, ICT grid routing, microwave principles, ICT grid security risks Competencies: use a complex communication system, design a computer grid, design processes, record transmitter readings
	Information and communications technology installers and repairers	7533	Knowledge: procurement of ICT grid equipment, telecommunications backbone link, ICT communication protocols, direct dialling of extensions Skills: soldering electronic components, operating two-way radio systems, sealing cables, operating two-way radio systems
	Telecommunications engineering technicians	3833	Knowledge: electromagnetism, principles of electronics, theory of analogue electronics Skills: use a complex communication system, solder electronic components, perform analytical mathematical calculations, use repair manuals
62. Programming, consultancy and other activities related to information technology	Computer programmers	3820	Knowledge: software user interface design patterns, computer programming, interactive software development environment software Competencies: use an interface for specific applications, use methodologies for user-centred design, develop a software prototype
	Web and multimedia analysts, programmers and designers	2713	Knowledge: keywords in digital content, web analytics Skills: perform online data analysis, develop digital content, use customer relationship management software
	Computer systems operations technicians	3811	Knowledge: resource description system query language, query languages, database management systems Competencies: migrate existing data, administer ICT system, manage databases, analyse ICT systems
72. Research and development	Chemicals	2413	Knowledge: analytical chemistry, physics, scientific literature, oxidation, laboratory techniques, green chemistry Skills: managing research data, advising on the reduction of chemical use, implementing formulae in production processes, using chromatography software, analysing the composition of chemicals, manufacturing chemicals
	Industrial and production engineers	2431	Knowledge: engineering principles, project plans, mathematics, technical drawing, physics Skills: manage research data, perform data analysis, develop open source software, record test results

	Electronics engineers	2442	Knowledge: test procedures for electronic systems and products, battery management systems, principles of electricity, types of electronics, environmental legislation Competences: design electrical systems, modify technical drawings, develop electronic test procedures, use technical drawing software

Source: Prepared by the authors based on ESCO and the LANBIDE graduate survey.

Universities can contribute by providing expertise in artificial intelligence and materials science in their curricula and preparing part of the future workforce[47]. In this sense, multi-institutional funding could be a strategy to support the human resources portfolio, skills upgrading of existing staff, and workforce development programmes (Daniel et al., 2024).

The universities of the ACBC have programmes such as the Degree in Electrical Engineering, the Degree in Industrial Technology Engineering, and the Degree in Engineering in Renewable Technologies related to electricity grids. There are also programmes such as the Master's Degree in Smart Grid Control and Distributed Generation or the Integration of Renewable Energies in the Electricity System.

Vocational training also has an important role in the transition to sustainability in general and electricity grids in particular. Examples are the professional families of Electricity and Electronics, Energy and Water, IT, and Communications or Installation and Maintenance.

Table 12 Contents on electrical grids associated with professional families related to electrical grids in the ACBC

Professional family	Contents related to electrical grids
Electricity and Electronics	Workshop on electrotechnical installations, electrical-electronic equipment and grids 0522. Development of electricity grids and transformer stations 0959. Electrical, pneumatic and hydraulic systems
Energy and Water	0680. Renewable energy systems 0686. Renewable energy project 5106. Data collection and measurement of energy consumption
IT and Communications	3016. Installation and maintenance of grids for data transmission 0226. IT security 0227. Grid services 0370. Grid planning and administration
Installation and Maintenance	951. Electricity and electrical automatisms 0954. Electrical-electronic assembly and maintenance Electrical and automatic systems workshop 0128. Installation planning

[47] Universities remain a key figure in society. beyond academic education, they foster innovation and research, promote reflection and critical thinking, educating a substantial part of future employees (García-Aranda et al., 2024).

	0133. Assembly, quality and maintenance management 0133. Assembly, quality and maintenance management 5011. Intelligent production processes 5013. Grided Environments and the Internet of Things 5058. Models of electrical installations and communications

Source: own elaboration based on Department of Education (2019).

There is also another type of non-regulated training covering electrical grids knowledge. In this sense, in the ACBC, the training in Electricity and electronics and smart grids offered by the Zamudio Technology Park, among others, can be highlighted (Fernández Gómez & Larrea Basterra, 2022b).

In the framework of the competences needed to reduce environmental impact, the European Skills, Competences, Qualifications and Occupations (ESCO) drew up a catalogue of 571 *green skills*, establishing relationships between them and the occupations for whose adequate performance they are needed (Orkestra, 2023). ESCO also identifies green skills for 342 occupations organised under the CNO.

Table 13 Number of occupations, according to 4-digit CRO, by green potential indicator

Green potential	Number of occupations	Percentage of total occupations
High (>20%)	26	7,6%
Medium-high (10-19%)	26	7,6%
Medium-low (5-9%)	54	15,8%
Low (<5%)	236	69,0%
Total	342	100%

Source: (Orkestra, 2023).

With this information, the occupations were identified according to their green potential, and the following four occupations related to electricity grids were identified (Orkestra, 2023): (i) electrical engineers, (ii) technical engineers classified under other headings, (iii) technicians in energy production facilities and (iv) manufacturing industry managers. There are also other grid-related occupations such as directors of information and communications technology services and professional services companies, electrical, electronic and telecommunications engineers, database and computer grid specialists, technical draughtsmen and draftsmen, supervisors in manufacturing engineering, computer programmers, construction and related electricians, other electrical equipment installers and repairers, electronic and telecommunications equipment installers and repairers, and labourers in manufacturing industries.

Finally, the number of employed persons aged 16 to 64 in the ACBC in occupations with high green potential was estimated (2022), finding, for example, that the occupation Electrical, electronic and telecommunications engineers had 7,392 employed persons, 0.8% of the total number of employed persons (Orkestra, 2023).

2.4.6 Social and institutional capital

The last lever, social and institutional capital[48] , according to Orkestra (2021), reflects "the system of rules and organisations that structure social interactions", thus making it possible to generate economic and social value. To this end, it is necessary to promote "innovation projects that foster cooperation between new combinations of agents with different capacities, which can create novel solutions to major socio-economic challenges". Two key elements are the quality of public institutions and cooperation between companies.

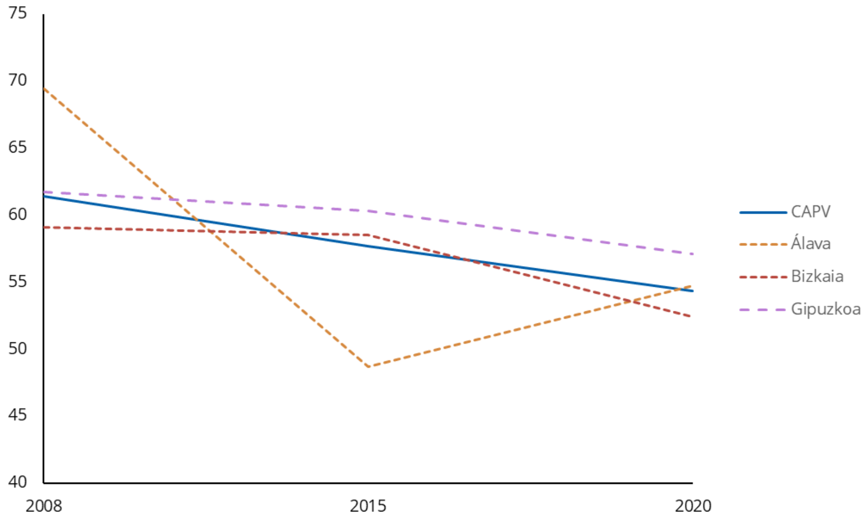
The development of electricity grids, both because of their need for sustainable transition and because of their capacity to generate employment and local economic activity, requires taking advantage of the strengths available in the territory to tackle ambitious projects. This is even more relevant in an environment in which there is social opposition to the use of available natural resources (e.g., natural gas extraction), to energy generation infrastructures (e.g., wind turbine parks), to the development of grids in the ACBC[49] and, to a lesser extent, to the deployment of distributed energy resources. Graph 8 shows that more than half of the population is unfavourable to installing new generation infrastructure, with some differences by historical territory, with Vizcaya having the lowest acceptance and Guipúzcoa having the highest.

To deal with this type of situation, it is necessary to strengthen the culture and awareness of the energy transition towards decarbonisation, energy efficiency, and support for renewables. In this area, the energy communities can play a fundamental role (where it has already been pointed out that the ACBC is a national leader) by favouring social acceptance of changes at the energy level, hoping to improve the acceptance of the energy transition.

[48] This lever overlaps with some elements of the structural context of Orkestra's competitiveness framework.

[49] For more details on this subject, see López Mosquera & Fernández Gómez (2023).

Graph 8 **People with favourable attitudes to the installation of renewable energy parks (%)**



Source: Mosquera López & Fernández Gómez (2023).

This situation is replicated in the case of electricity grids, with the rejection of Solaria's project for three solar parks in Álava and a high voltage grid to transport electricity to the port of Bilbao, as well as the project promoted by Forestalia which would involve the development of a high voltage grid crossing up to 12 provinces and in particular they oppose one of the lines already approved by the Ministry (between Tauste and Júndiz) (Lázaro, 2024).

Similarly, infrastructures involving different countries also suffer from a lack of acceptance. For example, the electricity interconnection that will link Spain with France through the Bay of Biscay has generated opposition on both sides of the border (Pereda, 2024a).

The Basque Government has limited competences in the field of energy. These are focused on promoting R&D, energy policy and planning in the territory, supporting the development of new infrastructure projects in the territory (e.g., interconnections), facilitating procedures and granting authorisations, and facilitating the development of new infrastructure projects in the territory (e.g., interconnections) (Álvarez Pelegry et al., 2013). However, in the field of electricity grids, Basque public institutions can act in three areas[50]: (i) the regulatory framework, (ii) investment incentives (in grids and R&D), and (iii) social acceptance.

[50] In any case, the Basque Government has few powers in establishing the regulatory framework for electricity grids and cannot directly incentivise investment in grids, only R&D and installations that can be classified as innovative.

The first two elements (the regulatory framework and investment incentives) are closely related insofar as the transmission and distribution businesses of electricity grids are regulated, and the elements listed below have a dual character of regulation and incentive[51].

According to Larrea Basterra & Mosquera López (2024), one of the key regulatory incentives is a stable, fair and predictable regulatory framework. It is often key for investors' investment and location decisions to have an attractive framework in terms of remuneration, which protects the right to property and the principles of company law. Similarly, P. Chaves et al. (2021) establish the need for "a clear regulatory framework with rules for the development of this type of projects and appropriate financing mechanisms, especially for regulated actors".

In this area, the EU is developing a regulatory framework that must be implemented throughout the EU, and that can generate an environment of stability (although this does not mean that it is simple). By way of example and related to grids, one can point to Regulation (EU) 943/2019 concerning the internal electricity market, which, in article 14, establishes that the remuneration methodologies of grid operators must provide incentives for innovation, in the interest of the consumer, in areas such as digitisation, flexibility services, and interconnections.

Mention can also be made of Directive (EU) 944/2019 on common rules for the internal market in electricity, which indicates the need to adapt the remuneration schemes of distribution system operators in EU countries to new challenges by incentivising flexibility. Likewise, this Directive places emphasis on the distribution grid development plans that grid operators must submit at least every two years to the regulatory authority, with the necessary investments over five to ten years, detailing the main infrastructures required to connect new generation facilities, electric vehicle charging points, etc., measures such as demand response or energy efficiency, and updating the needs for digitalisation of the grids and the necessary investments.

The next regulatory element/incentive refers to the capacity of Basque public institutions to influence regulation. Even though competences in this area lie at the national level, the ACBC can influence decision-making by preparing reports on grid needs for business activity or when approving regulations at the national level.

A third element relates to regulatory innovation mechanisms[52] that can be useful for testing new services and business models, limiting risk, and providing valuable information to guide

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[51] For more details on regulatory constraints on network investment see section 2.4.3.

[52] Regulatory innovation models are classified according to two dimensions: where the innovation takes place, and which actors are involved. Crossing these dimensions, four options are distinguished in the field of electricity grids*:* "(i) initiatives for the deployment of technologies that are implemented throughout the distribution system by the distribution system operator, such as, for example, the deployment of smart meters; (ii) pilot projects that are only carried out in specific areas of the grid, also by the distribution system operator; (iii) regulatory pilot projects that are system-wide innovations where both the distribution system operator and the market agents participate; and (iv) regulatory *sandbox* projects that are implemented in limited areas of the grid and where both the distribution system operator and the market agents participate in their development" (P. Chaves et al., 2021).
According to data obtained from EU grid operators, pilot projects in specific areas are the most widely used. Regulatory pilots and *sandboxes* are more recent and have not yet been widely implemented (P. Chaves et *al*., 2021).

future regulatory changes. In this area, Royal Decree 568/2022, of 11 July, approved the general framework of the regulatory test bed (sandboxes) for the promotion of research and innovation in the electricity sector and, in particular, to promote solutions in the field of renewable energies and the development of new business models in electricity infrastructure, smart grids and storage.

Related to the stable regulatory framework, a fourth element to act on concerns the design processes of grid planning and the processing of investments. In Spain, it is necessary to simplify processing procedures given that there is no agility in this field because too many agents are involved. Likewise, the regulation of access and connection must be updated to include new types of consumption, together with the methodology for calculating remuneration, where the risk associated with this type of activity must be considered (Pwc, 2023).

Regarding social acceptance, a strategy should be developed in collaboration with companies and citizens that addresses social acceptance and the elements that favour it. In this way, we should have our socialisation strategy, adapted to the concerns of the population of the ACBC and developed with them, to be used when considering energy infrastructure projects (grids in this case, but energy infrastructures in general). This strategy could increase the acceptance rate, even though, as pointed out by Mosquera López & Fernández Gómez (2023), acceptance is not always guaranteed.

From a business point of view, according to ENTSO-E (2024), coordination between transmission system operators (TSOs) and distribution system operators (DSOs) must be strengthened. Strengthening coordination between them has already been highlighted as a key issue in the R&D Roadmap 2020 - 2030 and is gaining more importance, considering that a relevant part of renewable energy generation is connected at the distribution level, as will be storage and demand-side management.

The 3E-2030 Strategy includes electricity grids that align with the orientation of technological development, actions, and initiatives. One of the issues it raises refers to technological and business collaboration, where to favour the positioning of Basque companies in the world of smart grids, the Strategy considers it advisable to increase the cooperation between companies and agents, ranging from research to application projects in real environments (EVE & Basque Government, 2017).

The ACBC has an Energy Cluster that brings together different value chains, comprising producers and distributors of various energies, manufacturers of capital goods and components, engineering companies, and other service companies specialising in the energy sector. It also has a small core of large companies (some of which are leaders in their activity) and a larger number of small and medium-sized companies (Orkestra, 2015).

In this sense, and as has been mentioned, the ACBC is characterised by having a solid industrial base and extensive business experience in the electricity value chain, made up of companies that manufacture components or products necessary for the activity of electricity grids. Likewise, there are service and engineering companies, technology centres, educational centres, universities, associations, and public bodies linked to electricity grid activity.

The Energy Cluster is an example of business collaboration, among others, in the field of electricity grids. Non-profit-making, it was set up in 1996 in "the framework of the Basque Government's policy of boosting the competitiveness of the industrial fabric" (Clúster Energía, 2024). It brings together companies and entities from the energy cluster of the ACBC, and its mission is to promote the competitiveness of the energy sector in the ACBC through collaboration. One of its main strategic areas is smart grids, where it has a group of Basque companies with a long history that have joined together under the Smart Grids Basque Country brand (see section 3.3.1). 3.3 for more information on the companies and entities that comprise the value chain), which join forces and seek to position the ACBC as an international benchmark, participating in different collaborative R&D projects (Neosub, SecureGrid, RESINET, etc.).

3. Grid investment needs and opportunities for companies in the Basque Country[53]

The IEA (2023c) estimates approximately 80 million kilometres of existing electricity grids worldwide. Additional investments are required, which, according to the STEPS[54] and APS[55] scenarios of the International Energy Agency (IEA), imply an increase in grid extension of 18% from 2022 to 2030 and an increase of 20% in the NZE scenario[56].

Not only is a greater extension of the grid necessary, but also the renewal of current infrastructures, their digitalisation and automation, and their adaptation to the needs of new system agents (e.g., prosumers, aggregators, and distribution grid operators), as well as their adaptation to climate change. In fact, in the PSA scenario, the equivalent of the current electricity grid must be added or renewed by 2040 (IEA, 2023a).

The IEA (2023a) estimates that global grid investments should roughly double by 2030, reaching 600 billion US dollars (US$) of annual investment, with an emphasis on investment for digitisation and modernisation of distribution grids.

Developing economies have a higher investment gap with more advanced economies and have had recent trends of decreasing investment. In contrast, more advanced economies have had a stable investment trend but still need to increase investment to be in line with the rapid deployment of renewables and the acceleration of electrification. In this respect, investments have been announced to modernise and digitise electricity grids (IEA, 2023b):

- At the end of 2022, the European Commission presented the EU action plan Digitisation of the energy system with estimated investments of EUR 584 billion in the European electricity grid by 2030, of which EUR 170 billion will be earmarked for digitisation (e.g., smart meters, automated grid management, digital technologies for metering and improved field operations).
- China plans to modernise and expand its electricity grids with US$442 billion in investments from 2021-2025.
- Japan announced a US$ 155 billion funding programme in 2022 to promote investments in smart grids.
- India launched an investment plan in 2022 to support energy distribution companies and infrastructure with US$ 38 billion.

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[53] As has been done so far, this chapter presents information on investments in transmission and distribution networks on the basis of the available data.

[54] The IEA's *Stated Policies Scenario* (STEPS) assumes that the direction of energy system progression is maintained based on current energy, climate and industrial policy conditions.

[55] The IEA's *Announced Pledges Scenario* (APS) assumes that all national climate and energy targets are met on schedule.

[56] The IEA's *Net Zero Emissions by 2050 Scenario* (NZE) assumes that the global energy sector achieves net zero CO_2 emissions by 2050.

- The United States announced in 2022 the Grid Resilience Innovative Partnership Program (GRIP), with US$10.5 billion in funding to support the improvement and expansion of the country's electricity grids.
- Canada has a US$100 million Smart Grid Programme to support deploying smart grid technologies and smart integrated systems.

3.1 Investment needs in the European Union

According to EY & Eurelectric (2024), 36 billion per year, but this figure should double by 2040 and multiply by 1.7 times by 2050 to support the growth of the electricity system. Successful flexibility measures (demand or supply and storage, such as batteries for electric vehicles) will result in lower investment needs.

The European Commission in the Grid Action Plan estimated for 2024-2030 an investment of 584 billion euros in electricity transmission and distribution grids for the EU-27 as a whole (European Commission, 2023)[57]. Following the publication of the Action Plan, the Commission launched a "Participation Pact for early, regular and meaningful involvement of stakeholders in grid development (National Regulatory Authorities (NRAs), project developers and civil society)". It aims to bring together representatives of the electricity sector to raise public awareness of the crucial role of grids in accelerating the transition to clean energy.

The Covenant is based on five pillars: (i) design and implementation of national and European communication activities on the key role of transmission and distribution grids as enablers of the energy transition; (ii) joint cooperative effort between national and local authorities, (iii) commitment by Member States to increase their efforts to accelerate grid projects, (iv) dialogue between ministries, regulators and transmission and distribution system operators and (v) provision of the necessary organisational conditions for all parties involved in the authorisation or participation processes.

Most grid investments in the EU will occur within borders, both at the transmission and distribution level, but interconnections will also play a key role (European Commission, 2024c).

For its part, EY & Eurelectric (2024) estimates that addressing future challenges would require a doubling of investment in distribution grids by 2040 and a 1.7-fold increase by 2050. It believes

[57] In addition to an increase in electricity consumption of around 60% by 2030, other assumptions made are:

- Wind and solar power generation will increase from 400 GW in 2022 to 1,000 GW in 2030, including offshore renewables (317 GW), which must be connected to land.
- Most of the investment will be made within the borders.
- Around 40% of European distribution networks are more than 40 years old and need to be modernised.

that, with innovation in distribution grids and an appropriate regulatory regime, investment could be reduced to EUR 55 billion, down from the currently estimated EUR 67 billion[58].

This requires a commitment to modernise, standardise, and reinforce electricity grids to achieve higher penetration of renewables, focus on electrification, stabilise prices and improve energy security (Editorial Staff, 2024). Emerging strategies or grid innovation revolve around three areas: (i) early investments that proactively size grid capacity constraints and demand surges; (ii) excellence in asset management where real-time data and AI are used to optimise asset performance; and (iii) grid flexibility services to manage demand during peak periods.

Failure to meet the investment target could risk up to 74% of potential connections of technologies needed for decarbonisation, such as electric vehicles, heat pumps, and renewables (EY & Eurelectric, 2024).

ERT (2024), based on the study by Monitor Deloitte et al. (2021), estimates that the construction and upgrading of energy infrastructure in the EU-27 will require a total investment of EUR 800 billion by 2030 and up to EUR 2,500 billion by 2050 in transmission and distribution grids.

Tsekeris et al. (2024), also for transmission and distribution electricity grids, estimate a gross investment needed to reach the targets of 302 billion euros in 2030, 400 billion euros in 2035, and 411 billion euros in 2040[59].

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[58] Estimates were made for distribution networks, in the period 2025-2050 for the EU-27 + Norway, using data from the European Commission's Fit for 55 and REPower EU programmes. The analysis was performed based on information from DSOs, which together serve more than 60% of European energy users, National Integrated Energy and Climate Plans (NECPs), Network Development Plans (NDPs), data from Ernst & Young (EY), and following the methodology of Imperial College London (ICL).
The main assumptions made include the following:

- Increase in demand by 80%, comparing the 2020 level (about 2,500 TWh) with 2050 (about 4,600 TWh). The buildings, industry and transport sectors will be responsible for 90% of this demand.
- Increase of renewable generation by 600%, comparing 2020 (about 500 TWh) with 2050 (about 3,600 TWh). 70% of renewables will be connected to the grid in 2050 compared to 20% today.
- Electrification: electricity will account for 60% of total energy demand in 2050, up from 20% in 2015 (251 million heat pumps and 237 million electric vehicles).
- Demand is the *driver* for 43% of the investment need, grid replacement and modernisation for 27%, generation for 12%.

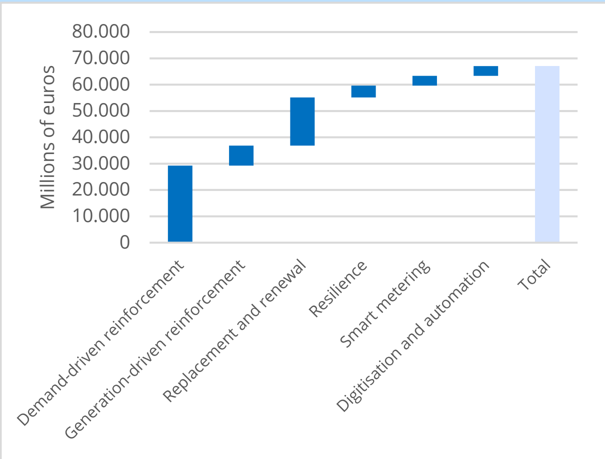
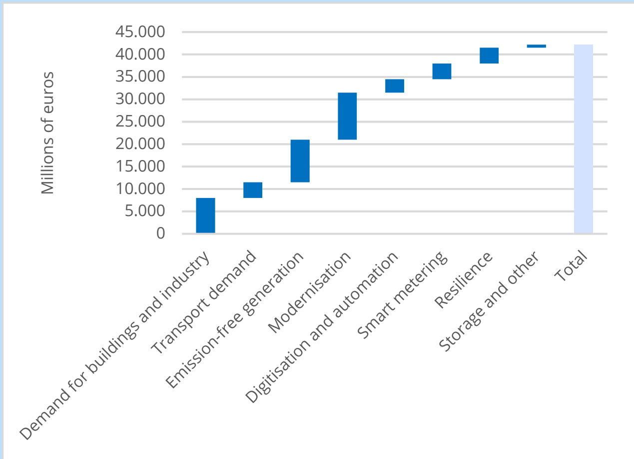
[59] For its Paris Agreement Compatible (PAC) for Energy Infrastructure scenarios, it assumes a 65% reduction in GHG emissions by 2030, net zero GHG emissions in 2040 and 100% renewables in Europe in 2040. It also proposes:

- A 20% improvement in energy efficiency by 2030 compared to 2020.
- A phase-out of coal in the EU by 2030.
- A phase-out of gas-to-electricity in the EU by 2035 and the sale of internal combustion engine (ICE) cars.

In this context, proactive investments must be made to address decarbonisation through the use of renewables in electricity as well as their development through rigorous regulation adapted to the situation (General Secretariat of the Council, 2024).

As can be seen in Table 14, the two main sector studies on investment in distribution grids establish that the greatest needs come from the electricity demand side due to electrification and the boost from the generation side.

Table 14 Estimates of investments in electricity distribution grids in Europe

Average annual investment EU27+Norway (2025-2050) (EY & Eurelectric, 2024)	Average annual investment EU27+UK (2020-2030) (Deloitte et al. Monitor, 2021)[60]
	

Source: translated and reworked from the sources indicated.

- A phase-out of oil derivatives and nuclear power in the EU by 2040.
- The use of hydrogen as domestically produced renewable hydrogen (H_2).

[60] Estimates have been made for the period 2020-2030, for the EU-27 + UK and for the distribution network. They are based on data from 10 distribution system operators (DSOs) and the following assumptions:

- Electrification progress through 40-50 million heat pumps in the residential sector; 50-70 million electric vehicles and industrial demand growth of 335 TWh and sustainable fuels generated with electricity (P2X). Electricity demand will increase by 1.8% per year until 2030 compared to 2017 (11% in the transport sector, 1.6% in industry, 0.9% in the commercial sector and 0.6% in the residential sector).
- Increase of 470 GW of centralised renewable generation, 40 GWh of self-consumption and where around 70% of the renewable capacity will be connected to the distribution grid.
- Energy efficiency and conservation measures (e.g. 50% of electric vehicle charging to be done in *off-peak* hours) as well as smart metering deployment.

In summary, more than 7 million kilometres of power lines at all voltage levels for distribution and transmission will need to be renewed by 2050, as well as more than 43,000 kilometres of additional cables at the transmission level. To this end, the demand for grid components (e.g., cables, converters, and substations) is expected to increase and exceed the manufacturing capacity in Europe (European Commission, 2024c).

As a consequence, supporting the EU grid manufacturing industry and addressing current barriers (e.g., lack of standardisation, access to raw materials, and security risks associated with third-country suppliers) is essential to reduce delays linked to the supply chain of grid components and enable the proper deployment of infrastructure (European Commission, 2024c).

3.2 Investment needs in Spain

According to the Electricity Transmission Grid Development Plan 2021-2026, the total estimated investment amounts to 6,964 million euros, of which 1,193 million euros are for interconnections[61], 1,154 million euros for the initial grid (for the integration of renewables) and the rest for new actions (Red Eléctrica & Government of Spain, 2020). For its part, the National Integrated Energy and Climate Plan (NECP) established for 2023-2026 investments of 4,554 million euros associated with electricity grid infrastructure, with an average annual investment volume of 759 million euros (Miteco, 2023)[62]. The 2023 NECP also estimates a total cumulative investment of 294 billion euros by 2030, of which 18% (i.e., 52.92 billion euros) is earmarked for grids[63]. In any case, the amount of investment needed in grids is higher than the existing investment limit.

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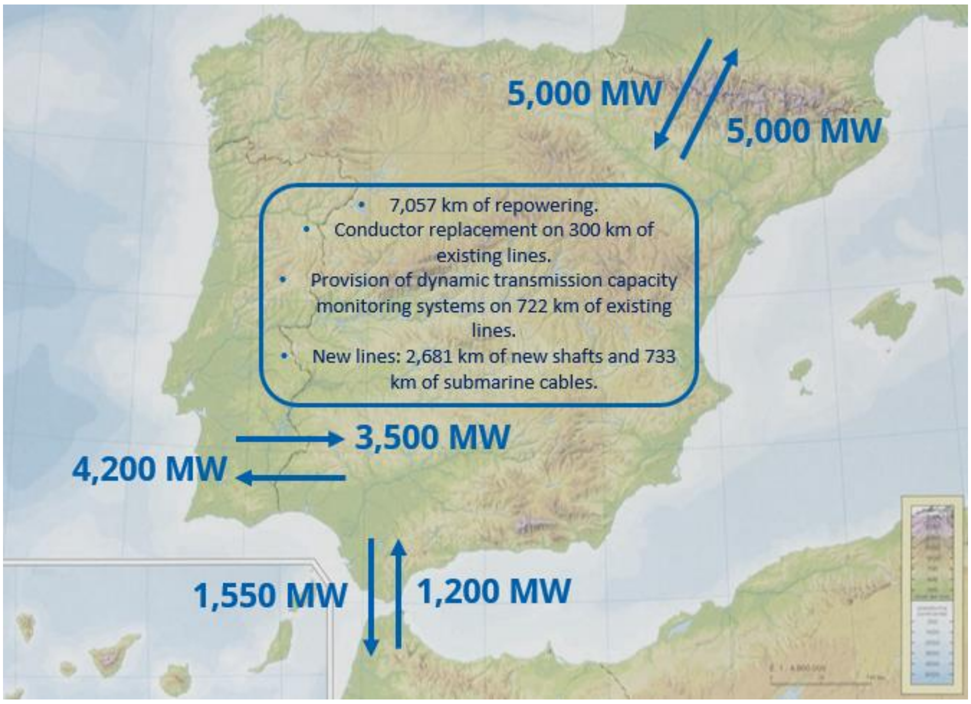
[61] According to Red Eléctrica & Government of Spain (2020) the strengthening of international interconnections is essential to improve the integration of renewable energies. To this end, the Electricity Transmission Grid Development Plan 2021-2026 includes three interconnection projects: (i) the Northern interconnection with Portugal, (ii) the Bay of Biscay interconnection with France for 2026-2027 and (iii) a third electricity interconnection with France for 2026-2027 and (iv) a third electricity interconnection with Portugal for 2026-2027 (Red Eléctrica & Gobierno de España, 2020).
Although both the Electricity Transmission Network Development Plan 2021-2026 and the French Multiannual Energy Programming 2024-2028 envisaged interconnections between Spain and France via Navarre and Aragon, the Spanish Government has not yet developed a plan for the interconnection between Spain and France (Ministère de Transition Écologique et Solidaire, 2023; Red Eléctrica & Gobierno de España, 2020). CRE (2024) ruled out any further interconnection projects with Spain when the interconnection with the submarine cable through the Bay of Biscay is completed.
This last submarine interconnection project suffered, in August 2024, a new four-month stoppage due to a court order (on the French side) because of the impact of the works on marine fauna (Legasa, 2024a). The final volume of the investment is estimated at around 3 billion euros 3 billion (Legasa, 2024b).
[62] The PNIEC envisages a total installed capacity of 214 GW by 2030, of which 160 GW will be renewable (19 GW of self-consumption) and 22 GW storage.
[63] The final version of the PNIEC published in September 2024 does not include these estimates (Miteco, 2024a).

The PNIEC also plans to undertake a digitalisation process that will enable transmission and distribution grids to improve monitoring, control, and automation. To this end, the Recovery, Transformation and Resilience Plan (PRTR) has been allocated 525 million euros. On the other hand, grids must be protected against the risk of cyber-attacks, as has happened in other countries such as the United Kingdom and Portugal, both in 2020; and improve their resilience to climate change.

In April 2024, specific modifications to the Electricity Grid Planning were approved, raising the inability of 6,000 MW of new industrial demand to be connected to the grid (Energy Newspaper, 2024). Specifically, the modification increased the number of planned actions to 73 (compared to the initial 64) and the associated investment to 489 million euros, but this was not enough to meet the grid access capacity of the industry[64].

Map 4 Investments in the electricity transmission grid 2021-2026 in Spain and associated benefits



[64] This is related to the rigidity of the transport planning process and its lack of agility to adapt to investment and network development needs in a scenario of increased electrification.

- The set of planned installations in the peninsular system allows a 68% integration of renewables in the peninsular system to be achieved, in line with the path established in the PNIEC.
- The new planned developments in the peninsular grid allow for a substantial improvement in the integration of renewables, with a 74% reduction in the generation discharges from renewable sources compared to the baseline grid case.
- 65% of the Balearic supply will be met from the mainland, leading to a substantial reduction in costs and emissions associated with Balearic supply.
- In the Canary Islands, the integration of renewables is doubled and the variable cost of generation is reduced by 30% compared to 2019.
- The planned reinforcement of international interconnections allows further coupling to the European single market and a substantial improvement in the integration of renewables.

	Mainland and Ceuta electricity system		Balearic electricity system		Canary Islands electricity system	
Benefits	CO_2 reduction: 5,300 kt/year	Annual profit: 980 M€/year	CO_2 reduction: 314 kt/year	Annual profit: 138 M€/year	CO_2 reduction: 1,240 kt/year	Annual profit: 325 M€/year
	Integration of renewables: 18,500 GWh/year	Annual return/ Investment year 1: 5.5	Integration of renewables: 280 GWh/year	Annual profit/ Investment year 1: 1.6	Integration of renewables: 2,015 GWh/year	Annual profit/ Investment year 1: 10
	Total investment: 2,160 M€/year	NPV: €17.2 BILLION	Total investment: 1,166 M€/year	NPV: €1,251M	Total investment: 385 M€/year	NPV: 6,040 M€.

Source: own elaboration based on Red Eléctrica & Government of Spain (2020).

In the field of electricity distribution[65], different estimates have been made by the sector. Energy and Society (2023) considers that meeting the challenges requires sustained investment in grids of between 2,500-3,500 million euros/year until 2030, without increasing electricity tariffs and with a socio-economic impact on wealth and local employment.

EY & Eurelectric (2024) 4.3 billion per year in electricity distribution grids (where 32% is for grid reinforcement due to increased demand, 16% for grid reinforcement due to supply, 33% for replacement and renewal, 2% for resilience, 12% for smart meters[66] and the rest for system automation and digitisation), in a context where equipment and installations need to be modernised, given that only 30% of these are less than 20 years old.

Despite this investment, it is estimated that in the EU, unit costs per consumer use of the grid will not increase due to increased usage after the investment (EY & Eurelectric, 2024) and will remain in the range of 50-55 euros/MWh (currently in Spain it amounts to 57 euros/MWh for domestic consumers) (Energy & Society, 2024)). In fact, as discussed above, it could contribute to reducing household energy bills by 45% by 2050. This requires removing investment caps[67], developing simplified processes and applying incentives. In this regard, in June 2024, the

[65] According to DSOEntity (2024) the concentration of distribution network operators in Spain is medium. The three largest DSOs supply more than 60% of electricity.
[66] According to Deloitte et al. monitor (2021)in 2017 the roll-out of smart meters exceeded 70% and by 2021 the roll-out across the country was almost complete.
[67] Due to the financial crisis and the need to contain costs, limits were set on investment in electricity grids in terms of percentage of GDP. However, in the current context of decarbonisation of the economy, high amounts of investment are required and are constrained by the above limits.

government opened a public consultation on the modification of the investment limit for transmission and distribution grids (Miteco, 2024b).

Deloitte et al. Monitor (2021) estimates for the sector a need for investment of 9 billion euros between 2020 and 2030 for the adaptation of electricity distribution grids due to increased electrification (due to the penetration of electric vehicles) and the deployment of renewables[68]. It also estimates an investment of 12 billion euros in the same period to replace obsolete infrastructure and its digitalisation. 1.9 billion will be devoted to adapting grids to climate change, mainly promoting the deployment of underground grids. High investments are also expected due to the age of distribution grids, especially low-voltage grids.

The urgency of undertaking such investments in grid infrastructure in Spain is worth mentioning. Due to the increasing saturation of the national grid, projects have been rejected (e.g., 15,000 MW of demand in the last four years and renewable projects (Acosta, 2024b)) and are expected to be rejected even more if it is not possible for anticipated investments in grid reinforcement and development, which facilitate the integration of future demand related to electrification, to be recognised within the remuneration.

This situation also affects the ACBC, where the electrification needs for decarbonisation, in general, are relevant and for the industry in particular. Failure to meet these requests means delaying and even failing to comply with the objectives of the PNIEC, encouraging, in the case of the ACBC, the possible relocation of companies.

3.3 Opportunities for companies in the Basque Country

As a result of the above, an increase in investment is foreseen. In this regard, and in the grid-related part, Vasiljevska et al. (2021) note that Spain shows the highest share of total European investment in smart grid and demand-side management projects, followed by Denmark and Italy. Spain also appears to have the highest share of total investment in the field of smart cities, followed by the Netherlands.

However, the characteristics of the Member States and national circumstances (size, population, and electricity landscape) must be taken into account in these observations. Thus, if the investment parameter is combined with GDP, Spain ranks ninth, above the EU average and behind Slovenia, Cyprus, Estonia, Greece, Greece, Bulgaria, Portugal, Belgium, and Finland (Vasiljevska et al., 2021).

In this line, according to Deloitte Monitor (2019), it is expected that between 2017 and 2030, more than 25 billion euros of electrical equipment goods will be traded in Spain due to investment in grids and the deployment of renewable energies. This includes metallic support goods, cables, transformers, power electronics, automation, protection and communication systems, and switchgear, among others.

[68] Most of the new renewable generation capacity (around 70%) is expected to be connected to the distribution grid. In Spain, this figure is around 25%.

In this way, considering the need for investment in grids, non-action and non-reinforcement of electricity lines could mean, in the case of the ACBC, a reduction in economic results both in terms of tax generation and the creation of associated activity and direct and indirect jobs related to the grids and industrial decarbonisation in particular, which these could favour.

First, this section presents an analysis of the electricity grid value chain in the ACBC, emphasizing the different segments or activities that comprise it. Second, an estimate is made of the economic multipliers of the branches of activity related to the companies in the grid value chain. This estimate is carried out using the Input/Output methodology and seeks to quantify the knock-on effect that an increase in the production of the branches within which the activities of the companies in the value chain are included can have on the economy of the ACBC.

3.3.1 Value chain of electricity grids in the ACBC

The ACBC is a region with high technological intensity and has one of the largest industrial clusters in Europe and a competitive *hub* in electricity grids and other energy-related areas. More than 80 companies form part of the value chain where there is no shortage of companies dedicated to the design, equipment, manufacture, installation, operation and management of electricity transmission and distribution grids positioned on the international scene (Energy Cluster, 2023).

In the Figure 7 shows a mapping of the companies that make up the value chain, separated by the different segments that make it up. In this value chain, the end user is the grid operator (in this case represented by TSO-Red Eléctrica and DSO-i-DE). The other links that make up the chain are circularly interrelated to offer the equipment and services necessary for the infrastructure, management and maintenance of the grid.

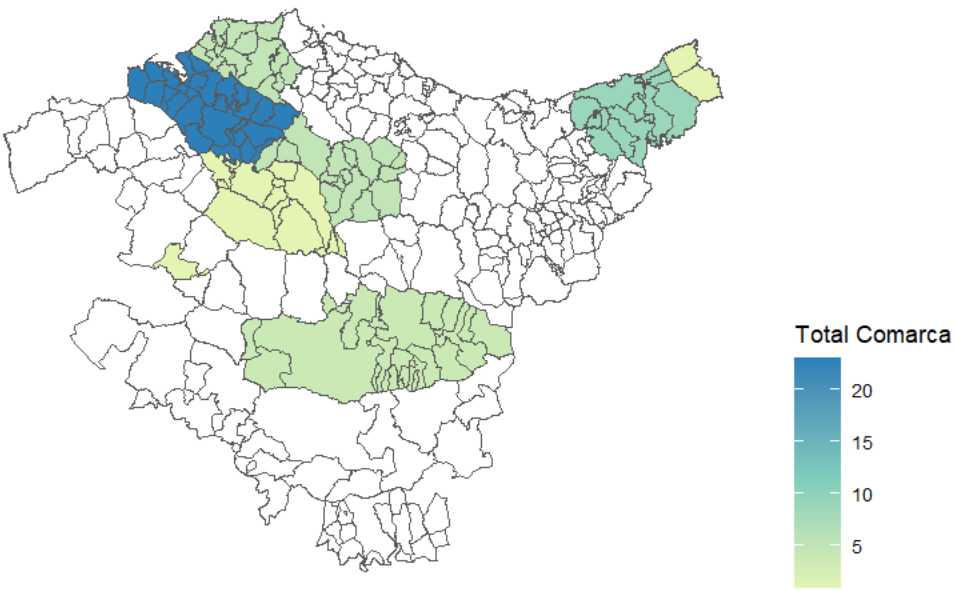
Figure 7 Companies and entities of the Energy Cluster of the ACBC related to grids

Note: This figure is based on the latest update of the companies in the Energy Cluster's electricity grid value chain.
Source: own elaboration based on Energy Cluster.

It is important to mention the effort that companies are making to integrate into their activity the different innovative electrical solutions that the value chain requires. Some companies have expanded their technological offer by creating industrial groups and/or frameworks that respond to the new needs of the sector.

Of this group of companies, a subset of 58 companies and entities has been analysed, for which complete information is available in the SABI database for the year 2022. Of these 58, 48 are based in the ACBC, and Map 5 shows their location by region. Notably, 71% of the companies are in Biscay, with a concentration of more than 20 companies in the Greater Bilbao region.

Map 5 Location of companies and entities in the electricity grid value chain by county (2022)



Note: for each region, the companies present in its different municipalities are added together.
Source: Prepared by the authors based on geoEuskadi.

Table 15 presents four additional financial indicators to those presented in the funding lever (see section 2.4.3). The EBITDA[69] of the 58 companies analysed amounts to 2,784 million euros, where the indicator for grid operators accounts for most of this figure. Concerning the other segments of the value chain, consumer-focused services and the involvement of new players, the smart metering and metering equipment business, and design, engineering, and consultancy services rank next in the indicator.

[69] Acronym for the financial indicator *Earnings Before Interest, Taxes, Depreciation, and Amortization*. Estimated in SABI as operating profit less depreciation of fixed assets.

The average liquidity ratio[70] for the group of companies is 223, indicating that the value chain companies generally have no problems meeting their short-term obligations. Only the grid operators had a ratio of less than 100, which does not mean they do not have difficulties, as discussed throughout the document, especially concerning investment limits and remuneration. Unlike the other links in the value chain, grid operators are companies that operate in a regulated market, with a policy of expansion and business that is stable over time and that generates recurring profits.

In terms of company profitability, on average, the financial profitability (ROE)[71] of the group of companies analysed is 2.32%, while the average economic profitability (ROA)[72] is 2.95%. In the case of data management, data analytics, and ICT suppliers, on average, they show both a negative ROE and ROA, while advanced digital equipment shows a negative ROE, and installation, maintenance, and after-sales services have a negative ROA. Meanwhile, grid operators, consumer-focused services, design services and smart meters and metering equipment show the highest average returns.

Negative average returns in some segments of the value chain indicate the need to continue to support companies with high levels of innovation, with potential for high productivity, and who are developing cutting-edge solutions necessary for the transition and development of grids in the coming years. To this end, it is crucial to remove barriers to growth and attract funding for companies committed to developing new technologies (European Commission, 2024b).

Table 15 Total EBITDA (thousands of euros), average of liquidity ratio, financial profitability (ROE), and economic profitability (ROA) (2022)

Activity	EBITDA (thousands)	Average liquidity ratio (%)	Average financial return (ROE) (%)	Average economic profitability (ROA) (%)
Grid operators	2.725.206	70,73	24,8	6,7
Design, engineering and consultancy services	31.864	345,74	12,8	8,0
Installation, maintenance and customer service	11.859	224,25	2,2	-1,8
Data analysis and management	-70.858	301,13	-45,8	-4,2

70 It is calculated as: $\frac{Current\ assets - Stock}{Liquid\ liabilities}$. This indicator measures the firm's ability to meet its short-term financial obligations, specifically it measures the firm's ability to provide sufficient cash for operations.

71 ROE or *Return on Equity* is calculated as the ratio of ordinary earnings before taxes to shareholders' equity. This indicator of a company's profitability measures the rate of return on shareholders' investment.

72 ROA or *Return on Assets* is calculated as the ratio of ordinary earnings before tax to total assets. This indicator of a company's profitability measures the ability of its assets to generate profits.

Consumer-oriented services and new user involvement	160.469	258,99	18,0	5,1
Advanced high and medium voltage grid equipment and digital solutions	-202.508	181,35	-22,4	4,2
Power electronics and storage	10.076	294,61	10,1	2,0
Smart meters and metering equipment	49.622	164,08	9,7	5,4
Testing and certification	3.154	105,35	6,6	2,4
Totals	2.784.321	222,65	2,32	2,95

Note: All companies classified in each activity of the value chain according to the Smart Grids Basque Country Energy Cluster initiative have been included in the calculations of each indicator. As a result, there are cases where a company appears in more than one activity. In such cases, the entire indicator has been included due to a lack of detailed information on the weight of each activity in the company's operation, resulting in duplicate companies. However, the totals have been calculated considering each company only once, so the sum by activity may not coincide with the sum by columns.
Source: own elaboration based on SABI.

3.3.2 Economic multipliers of the branches related to the value chain enterprises

This section calculates the knock-on effect that an increase in the production of the branches of economic activity, including the activities of the companies in the value chain of the grids, can produce on the economy of the ACBC. This is carried out using the Input/Output methodology, a method that seeks to represent the economic flow or interdependencies between the different sectors of an economy[73] and uses the inverse Leontief matrix[74] calculated from the symmetrical matrix[75].

[73] By means of the matrix representation of the source table and the destination table, grouped by homogeneous branches, it is possible to study the flow between them, as well as the evolution and relevance of the sectors of the economy. This representation gives rise to the symmetrical matrix or Input/Output table (Lora & Prada, 2023).
[74] The Leontief inverse is composed of the economic multipliers, r_{ij}or, in other words, how much of the sector's output is required to produce one euro of the sector's final output. i to produce one euro of final product of the sector, i.e. how much of the sector's output is required to produce one euro of the sector's output j. This multiplier not only considers the direct effect of higher demand from the sector on the sector, but also the direct effect of higher demand from the sector on the sector. j on the sector $i$sector, but also the intermediate consumption of the sector on the other branches, and in turn i on the other branches, and in turn the increase in the consumption of the other branches, and so on (Eustat, n. d.-c; Lora & Prada, 2023).
[75] From the symmetric matrix, it is possible to calculate the technical coefficients of the economy, where the technical coefficient a_{ij} corresponds to the quotient between the sector's purchases of intermediate inputs j to i and the total output of the sector j (X_{ij}/X_j). If the matrix A corresponds to the matrix of all

Using the latest symmetrical matrix published by Eustat, corresponding to the year 2015, the technical coefficient matrices and the Leontief inverse are calculated. Of the 85 branches of economic activity, eight branches were selected within which the segments of the value chain of the grids in the ACBC are included.

From the input and output multipliers it is possible to estimate the forward linkages (or push effect) and backward linkages (or pull effect) of a branch of economic activity. Table 16 presents the total backward linkages (direct and indirect) of the eight selected branches, where these linkages reflect the relative importance of the intermediate consumption (direct and indirect) of each branch with respect to the total demand of the economy (Lora & Prada, 2023)[76].

The highest backward linkage of the eight branches is in the electricity branch (and the second highest linkage of the 85 total branches), which includes grid operators, with a value of 1.965. This linkage reflects the carry-over effect of the branch, where a unit increase in final demand in this branch generates an increase of almost two euros in the output of the economy. The following branches are Telecommunications and Architectural and engineering services. The Electrical material and equipment branch ranks sixth out of the eight branches considered, with a value of 1.369.

Table 16 Backward linkages

No. Branch	Post	Branch	Full backward chaining
043	2	Electric power	1,965
061	34	Telecommunications	1,489
068	45	Architectural and engineering services	1,448
062	53	Computing	1,404
032	56	Computer and electronic products	1,402
033	67	Electrical material and equipment	1,370
042	68	Repair and installation	1,369
069	77	Research and development	1,243

Note: the column No. Branch indicates the identification number of the branch of economic activity given by Eustat. The Rank column indicates the ranking occupied by the branch among the 85 branches of activity, according to the value of its backward linkage (from highest to lowest).
Source: Prepared by the authors based on data from Eustat.

the technical coefficients, the vector X to the outputs of each sector and vector Y to the final demands per sector, then one can represent the output of the economy according to the Leontief model as: $X = AX + Y$. Thus, if the output vector is cleared, one has that $X = (I - A)^{-1}Y$where I is the identity matrix and $(I - A)^{-1}$ is the Leontief inverse matrix (Álvarez Pelegry & Díaz Mendoza, 2013).

[76] The calculations presented here are based on the indices of Rasmussen (1956) which use the coefficients of the Leontieff inverse matrix to calculate the direct and indirect effects of an industry on the economy as a whole. However, we do not calculate the coefficients of dispersion and dispersion sensitivity as only the columns or rows of the matrix are summed, without weightings.

For its part, Table 17 shows the total forward linkages (direct and indirect). This push effect measures how the production of all the productive branches increases in the face of a unit increase in the value-added of the productive branch under analysis. The electrical energy branch also ranks first in this case, with a total forward linkage value of 4.894, indicating that an increase of one euro in its value-added generates an increase of almost 5 euros in the output of the economy. Repair and installation, Telecommunications, and Architectural and engineering services are ranked next.

As in the case of backward linkages, the electrical material and equipment branch occupies one of the last places in its drag effect on the rest of the economy, in this case, seventh place out of the eight branches. It is important to note here that this is the only branch that corresponds exclusively to electricity grid activities, as the other branches of activity are not disaggregated to the level necessary to separate only grid activities. This may explain the lower tractor effect than the other branches, as well as the fact that we do not have updated information on the structure of the economy of the ACBC.

Table 17 Forward linkages

No. Branch	Post	Branch	Total forward chaining
043	1	Electric power	4,894
042	9	Repair and installation	2,292
061	12	Telecommunications	1,993
068	14	Architectural and engineering services	1,879
062	17	Computing	1,715
032	34	Computer and electronic products	1,344
033	49	Electrical material and equipment	1,169
069	82	Research and development	1,018

Note: the column No. Branch indicates the identification number of the branch of economic activity given by Eustat. The Rank column indicates the ranking occupied by the branch among the 85 branches of activity, according to the value of its backward linkage (from highest to lowest).
Source: Prepared by the authors based on data from Eustat.

4. Challenges for value creation by electricity grids. Key recommendations

As noted above, there is a clear need to adapt electricity grids to meet the growing demand for electrification and industrial decarbonisation, particularly in the ACBC. However, to achieve grid development, Spain must overcome several challenges, including: (i) optimising grid planning, taking into account the need for higher investments, (ii) existing barriers in the permitting process, (iii) inadequate coordination between investment needs and planning and regulation, (iv) regulation/retribution of grid activity, (v) lack of financing of the grid value chain and the need for coordination between the different incentives offered for the development of technologies and services, (vi) social acceptance of infrastructures and (vii) shortage of specialised labour and skills.

Grid planning

Grid planning is a rigid and complex process that is jeopardising grid stability due to the integration of renewable energies in combination with the growing demand for electricity. The rigidity and discretionality of transmission grid planning conditions distribution investments. The main obstacle is a grid planning process that does not anticipate specific investment needs. At present, the grid planning process is done on the basis of the most immediate connection needs for long periods of six years (Anacleto et al., 2024).

This way of planning is not able to cope with the speed and agility of the changing environment in the energy sector, where growth in electricity supply and demand is expected to be high but uncertain. However, regulation should support frontloaded investments, which, according to EU-wide estimates, could reduce the required investment in the grid by around 18% (EY & Euretriclec). Indeed, by way of example, in the summer of 2024, Red Eléctrica announced the nodes for holding the first demand-side grid access tenders (Acosta, 2024a). In total, seven were selected (Andalusia, Community of Madrid, Aragon, Castile and Leon, Community of Valencia, Catalonia and Castile-La Mancha), ignoring the existing needs in other territories such as the ACBC itself.

To resolve this situation, the flexibility of grid planning needs to be improved, and the needs of the transmission and distribution grids and the connection points between the two need to be coordinated. A proposal along these lines could be to take a proactive approach to planning, identifying present and future needs, i.e., anticipating and prioritising them. The planning, implementation, and review process should also be streamlined, e.g. with annual updates of the six-year plans. Distribution grid planning will also benefit from greater clarity on remuneration frameworks. This should consider not only the expansion of grids but also their digitisation and modernisation.

Obtaining permits

Planning implementation may be hampered by project permitting processes. In fact, it is estimated that the execution of the works will take between four and ten years. As an example, the investment in the offshore interconnection in the Bay of Biscay has been mentioned above, with long delays and increases in development cost estimates, but has also recently been paralysed in France because of a court order (on the French side) due to the impact of the works on marine fauna.

Improved permitting processes are particularly relevant in distribution grids, where there is no clarity regarding planning or deadlines for obtaining services at the EU level. In addition, European and national legislation is complex in terms of requirements, which hampers the impact assessment of grid infrastructures (European Commission, 2024c).

The granting of permits for grid deployment could be accelerated through streamlining solutions such as a one-stop shop for the granting of permits for transmission and distribution grid expansion, digitisation of procedures at local and national levels (European Commission, 2024c) and the creation of electricity corridors to facilitate the processing of permits under certain conditions. In this way, the necessary pace of decarbonisation must be matched so that grids do not become a bottleneck for the penetration of renewable sources or the electrification of mobility, among others.

Inadequate coordination between investment needs and planning and regulation

Implementation processes are hampered by limited collaboration between public and private sector stakeholders (regulators, developers, consumers, society, etc.). As an example, there is a lack of coordination between the existing regulatory framework and investment needs, as investments are limited to a percentage of GDP (0.13% and 0.065% of GDP for distribution and transmission investments, respectively) (Miteco, 2024b) instead of analysing real needs. This cap on GDP prevents all the grid investments needed to facilitate the energy transition and advance the electrification of the economy.

Consumers face lengthy processes to access the grid as there are more requests for connection than access points provided. Indeed, industrial demands and data centres were paralysed in 2024 because their requests have not been granted. To overcome this situation, a key element is to achieve coordination and collaboration between stakeholders in grid planning, deployment, and operation.

According to Anacleto et al. (2024), collaboration between the parties should enable renewable energy developers to be aware of grid constraints and demand projects (e.g., by publishing the current and future available capacity of substations). They also indicate that more projects of common national interest should be promoted to help speed up grid deployment alongside renewable energy and electrification projects. Moreover, they point out that grid access for renewable energy developers could be improved by offering technically standardised connection modules and easing connection requirements by allowing conditional connections with a pre-agreed level of constraint.

Regulation of stable, predictable, and sufficient remuneration for grid investment

Once the grid has been planned, even assuming that it is adapted and adjusted to the needs, the next challenge relates to the volume of investment required and other difficulties that add risk and sometimes result in increased investment costs.

Indeed, the current geopolitical environment highlights the challenges related to the supply chains of raw materials and equipment necessary to develop grids. There is a risk of equipment shortages, delayed deliveries, and price volatility. For example, transport and distribution equipment costs increased by 0.6 to 1.3 times in Europe in the last two years (Anacleto et al., 2006).

However, in this situation, there is a lack of clarity on the future regulation of investment remuneration, e.g., late compensation of investments without correction for inflation or limited visibility of future updates and deadlines for new renewable connections (Anacleto et al., 2024). In this scenario, it is necessary to bring clarity and predictability to the remuneration framework for investments and to establish a process for updating it, which adjusts to different economic contexts (e.g., considering higher inflation and interest rates).

To address this, supply chain challenges could be mitigated by standardising equipment to reduce costs and lead times, establishing long-term framework agreements with OEMs, and encouraging training and retraining initiatives. Also, remuneration-related regulations must be rapidly adapted to the situation at the time, so that inflationary periods do not delay necessary developments.

Value chain finance and investment incentives

Not only is it necessary to update the regulatory framework for investments in the electricity grid, but it is also necessary for companies in the grid value chain, as well as providers of products and services necessary for its development, to be able to attract financing. Many of these companies are offering (or seeking to offer) innovative products and services (such as those based on AI, the Internet of Things, blockchain, big data, etc.), the development of which implies that they have high levels of risk, but high growth potential (as noted in section 3.3.1they can be companies with negative or close to zero returns, but which are crucial for the modernisation, digitisation, and automation of the electricity grid).

Thus, it is necessary to develop financing models to attract venture capital and foster innovation in these companies, as well as models and mechanisms for financing electricity infrastructure projects, where long-term financial instruments are developed[77] to mobilise private capital and lighten the burden on public budgets, which are ultimately passed on to consumers (European Commission, 2024c).

Social acceptance

As in the case of renewable energy, the development of grid infrastructure projects also faces problems related to the social acceptance of the communities where they will be carried out. In fact, it was recently the case that neighbourhood communities rejected the development of three macro photovoltaic energy parks in Álava, which would generate electricity to be transferred to the Port of Bilbao. The rejection is not only of the solar parks but also of the

[77] See (Larrea Basterra & Mosquera López, 2024) for an in-depth discussion of the different types of incentives for investment in clean technologies.

construction of the high voltage line, planned to pass through the provinces of Alava and Vizcaya (Lázaro, 2024).

Citizens perceive costs for having renewable energy projects in their territory (e.g. in environmental and visual terms) that do not generate benefits for them (as they sometimes feel that the renewable energy produced does not stay in their municipalities, even though technically the physical production remains near its generation). This issue becomes even more relevant as renewable energies continue to be deployed, where many of the optimal areas of generation are not necessarily close to where demand is located, so getting electricity infrastructure projects in place is crucial to avoid congesting the existing grid and to be able to transport and distribute the electricity produced (European Commission, 2024c).

Promoting social acceptance and participation in the proper integration of renewables through investment in grids is a key element. This is possible if developers and governments (national and regional) commit to planning projects involving citizens at all stages, distributing costs and benefits fairly, and considering vulnerable groups. Social acceptance can also be promoted through citizen participation and education on energy, decarbonisation, and environmental sustainability issues (Mosquera López & Fernández Gómez, 2023).

Workforce and skills

Another key issue for the development of investments concerns labour and skills needs, considering that according to estimates, the demand for labour in the field of electricity grids will increase by 60% by 2030 (Anacleto et al., 2024). This is all the more relevant in the current context of the triple transition: energy-environmental, technological-digital, and demographic-social, the latter characterised by a reduction in the working-age population at European, Spanish, and ACBC levels (Fernández Gómez & Larrea, 2024).

There is a skills gap that creates barriers to innovation. This lack of necessary skills and qualifications, most notably those related to digitalisation, is becoming a barrier to investment. According to European Commission (2024b), around 42% of Europeans lack basic digital skills, including 37% of those in the workforce.

In this situation, it is necessary to optimise the use of available skills and competencies and ensure that people have access to education and retraining, as the competitiveness of territories is now less about costs and more about the knowledge and skills of the workforce (European Commission, 2024b).

Although the ACBC has the capacity for STEM training, the shortage of students must be addressed, paying attention also to the training of adults and the adaptation of people to the new needs of the labour market, updating the skills of workers throughout their professional lives.

In parallel, the education and training system needs to be more responsive to changing skills needs and identified gaps. Curricula need to be revised by involving employers and other stakeholders. European Commission (2024b) states the need to introduce a common certification system so that potential employers in the EU easily understand skills acquired through training programmes.

In the case of the ACBC and electricity grids, this will require an additional effort to attract talent. This can be resolved for smart grids by means of specific complementary interventions, which at the EU level are proposed with programmes that combine visas at EU level for students, graduates, and researchers. In the case of the ACBC, this is sought to be resolved through the development, among others, of study programmes such as the University of Deusto's Master's in Lifelong Learning in Innovation and Technology with dual training, which, in collaboration with public institutions and companies seeks to attract STEM talent from third countries to solve the existing problems here (University of Deusto, n. f.).

Final recommendations

As has been discussed throughout the study, not carrying out the necessary investments in electricity grids would not only put the decarbonisation of the economy at risk but would also negatively affect the competitiveness of companies and the territory. This impact on competitiveness is particularly relevant in the case of the ACBC, which has an industry with a significant weight in GDP, a complete value chain for the development of electricity grids, and an established policy of promoting R&D&I. The following elements are of particular importance:

- To accelerate the deployment of renewables to effectively reduce the energy bills of businesses and households and reduce the GHG emissions associated with energy production, it is necessary that grids do not become a bottleneck. Expansion, modernisation, automation, and digitisation of grids must happen alongside decarbonisation. Indeed, according to European Commission (2024c), for every euro invested in clean energy in Europe between 2022 and 2040, 0.9 euros should be invested in grids. High energy prices are a barrier to economic growth and to the competitiveness of businesses, which in the EU face prices twice as high as in the US.
- Investment in grids will allow for the continued development of the domestic electrical goods and equipment manufacturing industry, as demand for grid components is expected to exceed European manufacturing capacity. This is particularly relevant in the case of the Basque Country, which has an electrical equipment and material sector with a significant weight in the economy. On the one hand, it is necessary to give this industry greater support for investment in innovation and its positioning due to its high-quality standards that make it stand out in international markets. On the other hand, at the supranational level, the standardisation of grid components should be promoted, not only to accelerate the expansion of grids at lower costs but also to enable manufacturing companies to take advantage of economies of scale and increase their added value (European Commission, 2024c). This is paramount, given that supply chains for such equipment will be subject to high stress levels due to a lack of raw materials and talent, among others.
- An expansion and modernisation of grids in line with decarbonisation objectives will also promote the development of innovative technologies. Further promoting R&D&I of different technologies is crucial to provide solutions to the grid that involve lower levels of investment, while these developments can also be used by other sectors and make the companies and territories that invest in them more competitive.

In conclusion, electricity grids and the associated value chain must grow at the pace required for decarbonisation. New investment in grids will not only enable the electrification of industrial demand in the ACBC, bringing economic, social, and environmental benefits, but will also enable a reduction in unit distribution costs. In short, a new design of the electricity grid for the 21st century is needed to avoid the relocation of the Basque industry and its potential development. This will be possible if sufficient and efficient investment incentives are provided to enable the financing and timely development of electricity grid infrastructures (Larrea Basterra & Mosquera López, 2024). These incentives should encourage investment in anticipation, bearing in mind that in the case of Spain, particularly the ACBC, it is not just a matter of anticipating, we are already behind schedule.

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