ate Aliança para a Transição Energética

beta-i INESCTEC

Innovation, Challenges & Strategies

ATE Highlight Report

PRR Plano de Recuperação e Resiliência

REPÚBLICA PORTUGUESA

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EXECUTIVE SUMMARY

Within the framework of the Alliance for Energy Transition (ATE), two cornerstone documents were developed: the Ecosystem Map, prepared by Beta-i, and the Policy Report, produced by INESC TEC. This Highlight Report brings together and connects the key insights from both, offering an integrated perspective on Portugal's energy sector — its current state, emerging trends, structural challenges, and strategic pathways.

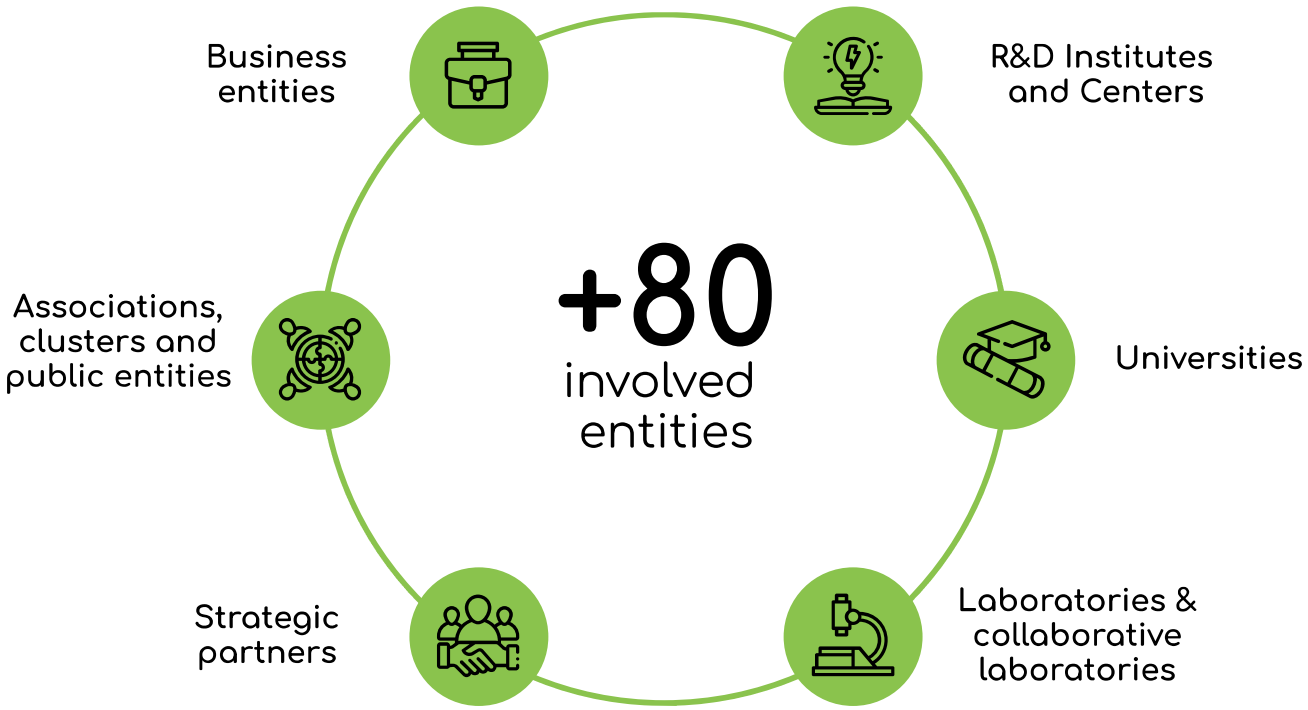
More than a synthesis, the report is designed to function as both a clear communication tool and a practical guide for ATE partners and for society at large. By bridging technical analysis with strategic recommendations, it aims to support decision-making, foster collaboration, and accelerate Portugal's journey toward a just, inclusive, and sustainable energy transition.

INDEX

CHAPTER 1

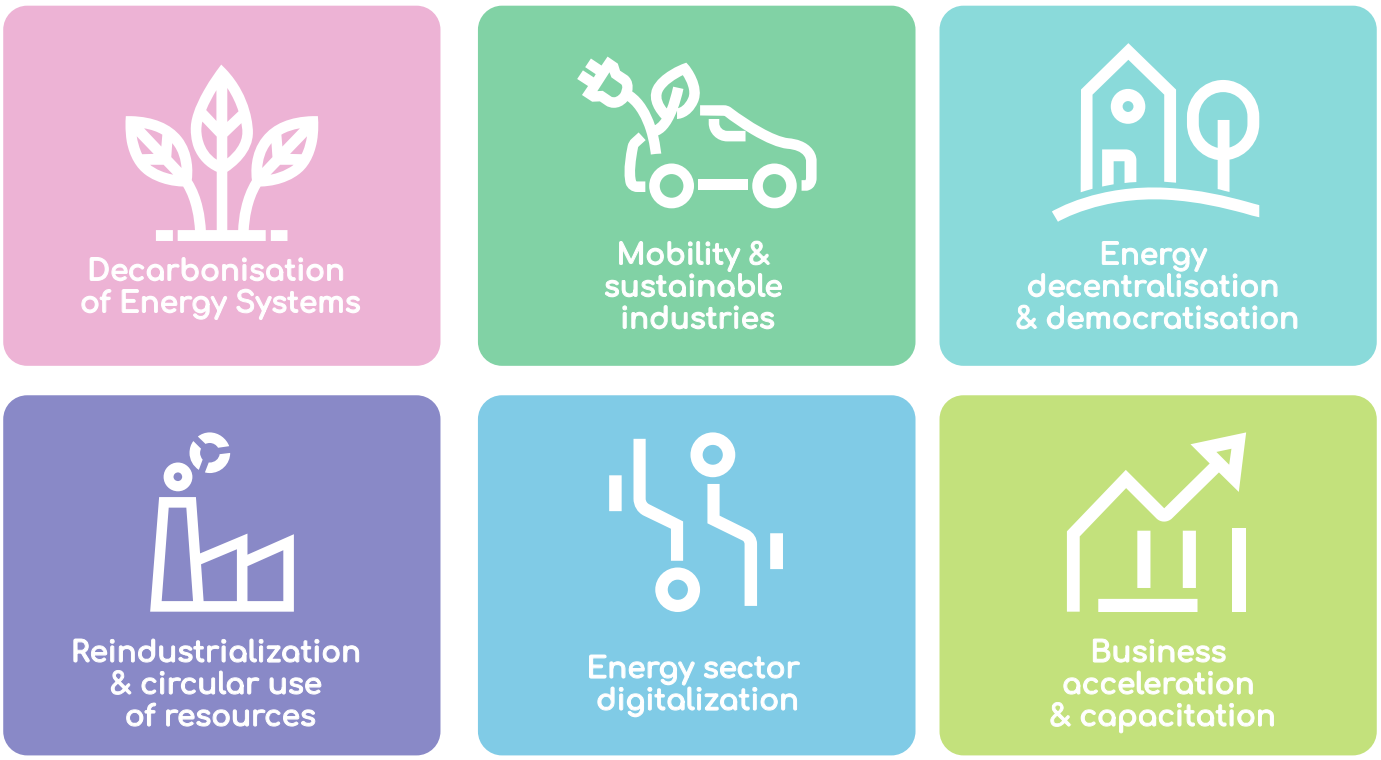
The ATE Agenda

The Alliance for Energy Transition (ATE) is a national initiative to accelerate the decarbonization of the Portuguese economy and strengthen Portugal's leadership in Europe's energy transition. Created under the Recovery and Resilience Plan (PRR) and aligned with the United Nations 2030 Agenda, the ATE brings together **more than 80 entities**, including companies, research centers, universities, startups, associations, and municipalities, in a joint effort to transform the energy system across all its dimensions.



The Agenda is structured around several priority axes: the decarbonization of the energy system, mobility and sustainable industries, energy decentralization and democratization, reindustrialization and circular use of resources, digitalization, and business acceleration and capacitation.

CHAPTER 1



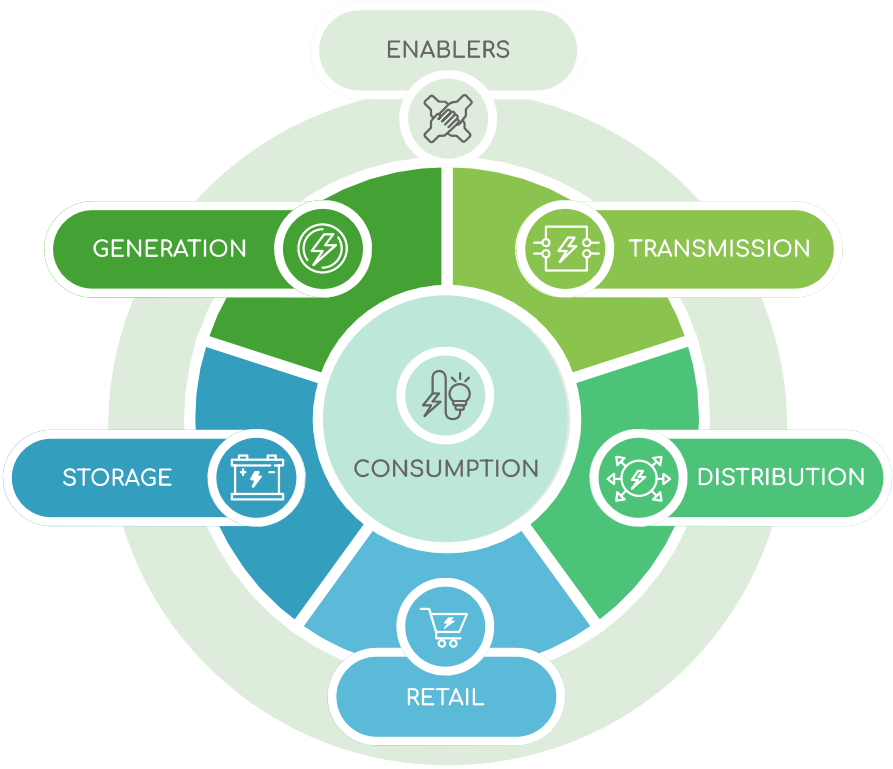
More than a technological strategy, the ATE represents a new form of collaborative governance, based on the articulation between major institutional and industrial players and local and emerging actors, enabling the acceleration of innovation while ensuring social legitimacy.

With robust investment and a diversified partner network, the ATE positions itself as a catalyst for the energy transition in Portugal. Its expected impact goes beyond the energy sector: it seeks to stimulate the creation of skilled jobs, attract foreign investment, promote balanced territorial development, and strengthen national competitiveness within the European context.

CHAPTER 2

The Current State of Portugal's Energy System

The Portuguese energy system is structured along a value chain that spans all stages, from generation to transmission, distribution, storage, consumption, and enablers. Although it may appear linear, this system operates as a highly interconnected network, where any change at one point reverberates across the entire structure.



Generation relies mainly on renewable natural resources and centralized production, yet demand continues to exceed domestic supply, sustaining the need for fossil fuel imports. Decentralized production has been expanding, with particular emphasis on self-consumption and energy communities, and **the country has already recorded days entirely supplied by renewable electricity.**

The integration of variable sources such as hydro, wind, and solar PV has been a hallmark of the electricity system since 2010, while technologies like biomass also contribute to decarbonization. In contrast, coal, fuel oil, diesel, and propane plants have experienced a sharp decline, whereas natural gas generation continues to play a critical role in ensuring system flexibility.

CHAPTER 2

In transmission, the national grid is managed by a single system operator, responsible for high-voltage lines and interconnections with Spain, which enable electricity imports. Since 2020, around 5% of the demand from large industrial consumers has been supplied directly through the transmission grid. Distribution, in turn, ensures the link between the national grid and end-users, progressively integrating renewable energy and smart grid technologies.

Despite this modernization, the distribution of petroleum products continues to depend on road transport. In 2020, mainland Portugal had 11 electricity distribution system operators (DSOs), with most activity concentrated in a single operator.

Retail operates in a liberalized market, allowing consumers to freely choose their supplier. There are also last-resort suppliers to guarantee supply for vulnerable or less active communities in the market. Retailers have diversified their offers, increasingly incorporating associated services such as e-mobility and storage solutions.

Electricity storage has historically remained centralized in pumped hydro systems integrated into dams. Alternative technologies, such as lithium-ion and solid-state batteries connected to renewables, are still at a smaller scale, although pilot projects exist, such as the battery installed alongside the Alqueva floating solar plant in 2022. Currently, investment efforts are underway to structure a complete storage value chain, with particular focus on batteries.

On the consumption side, energy is distributed across transport, residential, industrial, and services sectors. Self-consumption, although still limited in scale, has shown growing results, with units already injecting surplus into the Public Service Electricity Grid. Transport and industry remain highly dependent on fossil fuels, while the residential sector has recorded increased use of heat pumps and solar thermal. The entire ecosystem is supported by regulatory authorities, fiscal agencies, infrastructure operators, and technology providers, complemented by research and development institutions that generate knowledge for the system's sustainability.

Key indicators illustrate this diagnosis. Portugal's energy dependency was 71% in 2020, decreasing to 66.7% in 2023, the lowest level on record, mainly due to reduced gas imports. Primary energy consumption has remained stable since the drop caused by the pandemic, while final energy consumption has grown between 1.1% and 2.5% annually since 2018 (except in 2020 and 2021).

CHAPTER 2

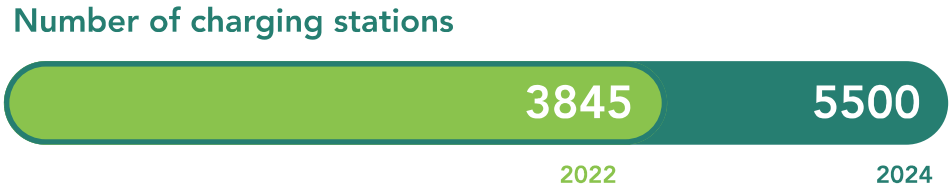
Electricity already accounted for around 25% of final consumption in 2023. Carbon intensity reached 263 $MtCO_2eq$ per million euros of GDP in 2021, while energy intensity indicators have followed a downward trajectory since 2020. Per capita consumption of both energy and electricity has also been increasing. Regarding renewables, they accounted for 56% of electricity generated in 2022 and 63.8% in 2023, corresponding to more than 35% of final consumption.

Installed renewable capacity reached 17,252 MW in 2022, with renewables representing 60% of gross final electricity consumption in the same year. The closure of thermal power plants contributed to a 31.9% drop in fossil-based electricity generation in 2023 compared to 2022, offset by hydro and solar PV. In self-consumption, grid-connected capacity reached 939 kW in 2022.

Infrastructure data adds further perspective: transmission losses stood at 1.98% in 2022, while distribution losses reached 9.84% in 2020; the Iberian Peninsula's interconnection capacity was set at 5% in 2023; and the distribution network had 6.3 million users in 2020. Grid-connected capacity in distribution reached 6,367 MVA in 2022. In terms of storage, there were 70 facilities supporting the national grid in 2023, with a total capacity of 4.1 GW.

Consumption patterns reflect the strong weight of transport and industry, which together accounted for more than 64% of final consumption in 2023. The transport sector represented 36.8% and returned to pre-pandemic levels, while industry accounted for 27.6%. The residential sector represented 17.5%. The share of renewables in transport was 8.61% in 2021.

CHAPTER 2



In e-mobility, the number of charging stations increased from 3,845 in 2022 to 5,500 by the end of 2024, with more than 250,000 registered users. Four energy communities were also licensed in 2023.

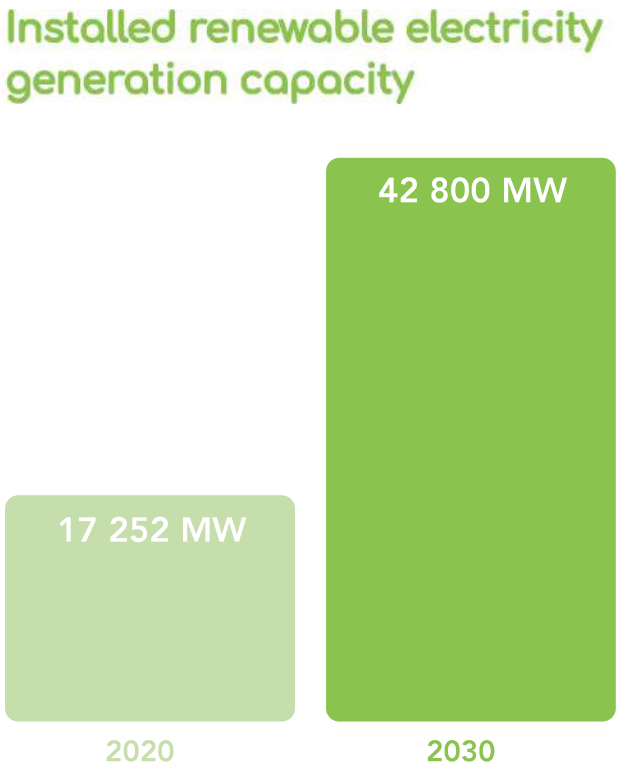
In summary, Portugal has consolidated important progress in renewable energy integration, energy efficiency, and reducing carbon intensity, but structural challenges remain. Energy dependency, the heavy reliance on fossil fuels in transport and industry, and the need to scale up emerging technologies such as green hydrogen and storage demonstrate that, despite a solid foundation, further investment and policy adaptation will be required to meet medium- and long-term goals.

CHAPTER 3

Smart Grids and Green Hydrogen as Growth Drivers

Portugal has been aligning its energy strategies with international commitments, particularly with European directives and the Paris Agreement, setting targets for decarbonization, carbon neutrality by 2050, and sustainable development. This commitment is underpinned by strategic frameworks such as the Roadmap for Carbon Neutrality 2050 (RCN) and the National Energy and Climate Plan 2030 (NECP).

Among the main trends, the expansion of renewable energy sources stands out. **Projections indicate that the share of electricity from renewables will reach 90% by 2030. Installed renewable electricity generation capacity is expected to more than double, from 17,252 MW in 2020 to 42,800 MW in 2030.**



Portugal has been a pioneer in integrating variable renewable sources such as hydro, onshore wind, and solar PV, whose shares continue to grow. Offshore wind also presents significant potential, with projects already in operation and ambitious expansion plans.

Electrification and growing energy demand constitute another clear trend. There is a strong orientation toward replacing final energy demand with electrified solutions, particularly in transport, heating, and industrial processes. Green hydrogen is emerging as a key vector for decarbonization, supporting different links of the energy value chain, promoting renewable integration, and enabling sector coupling. Plans are underway for the expansion of its production and for injection into natural gas networks.

CHAPTER 3

Improvements in energy efficiency are also visible. Indicators show efficiency gains relative to domestic output. Under the ATE Agenda, initiatives to modernize consumption systems in buildings and communities are multiplying, leveraging innovative materials and developing digital platforms to optimize energy management.

The modernization of energy infrastructure and the development of smart grids form another central pillar. The grids of the future are being designed to ensure reliability, efficient operation, and the integration of diverse sources. The sector is moving toward greater digitalization, with smart grids and advanced control systems that enhance efficiency and flexibility. Investment in storage solutions, such as pumped hydro, batteries, and flywheels, is essential to manage intermittent renewable sources and reinforce grid resilience. In parallel, decentralization is increasing, with growth in local generation, self-consumption schemes, and the establishment of energy communities, enabling consumers to play a more active role in the market.

Sustainable mobility is another expanding domain. The number of electric vehicles and charging points has grown significantly, with projections pointing to 25,000 charging stations by 2030. Investments are also being made in the electrification of public and rail transport, reducing emissions and oil dependency. The trend encompasses not only cars but also buses, trucks, ships, airplanes, and trains, reinforcing the commitment to green mobility.

Portugal is also investing in emerging technologies, integrating advanced solutions in solar, wind, batteries, and green hydrogen, while promoting digitalization and the application of Internet of Things (IoT)-based solutions to optimize operations, strengthen predictive maintenance, and improve energy efficiency. This movement is accompanied by policies and regulatory frameworks aimed at creating favorable conditions for the adoption of new technologies, including incentive measures, legal certainty, and integrated resource allocation strategies.

Finally, the reduction of energy dependency deserves particular attention, with a consistent movement toward greater self-sufficiency.

These trends confirm Portugal's strong commitment to transforming its energy sector, supported by ambitious environmental targets and the adoption of technological advancements that span the entire energy value chain.

CHAPTER 3

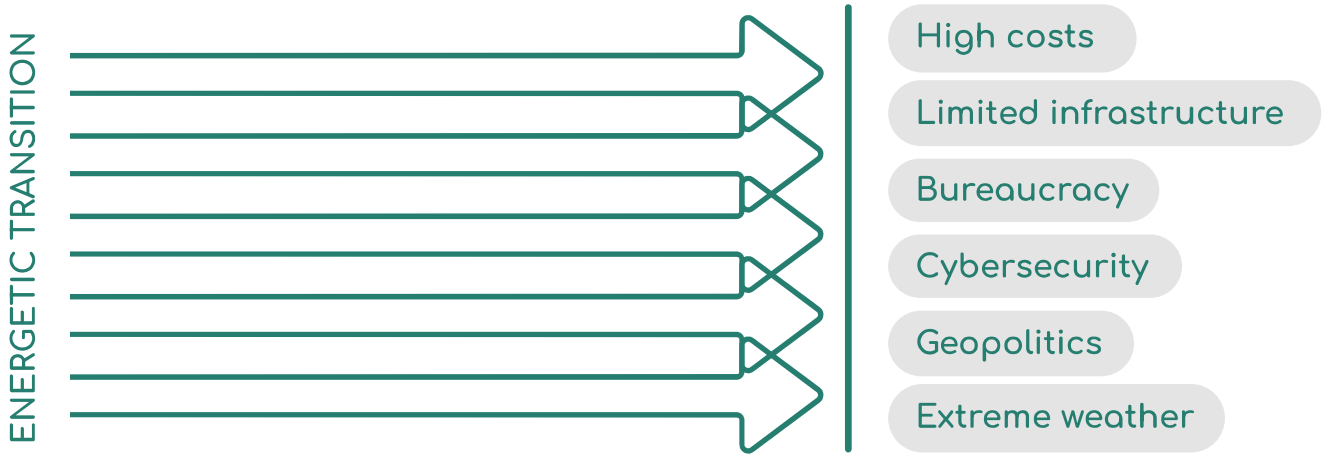
These trends find empirical validation in interviews conducted with leaders of Products, Processes, and Services (PPS) under the ATE Agenda. The identification of competencies and technological case studies, together with the development of a network of laboratories, confirms the focus on capacity building and innovation. The creation of interoperable digital platforms, algorithms, and management tools for teams, power grids, e-mobility, and renewable systems corroborates the trend toward digitalization and smart grids. The development of cloud solutions for consumption monitoring and forecasting reinforces infrastructure modernization. The adoption of circular economy methodologies, particularly in industrial processes and in the use of hydrogen, validates the growing integration of sustainability and circularity. Projects involving hardware and software installation for EV chargers and batteries, as well as multi-energy systems for industrial decarbonization, confirm the trends of sustainable mobility and diversification of energy vectors.

Taken together, both the testimonies gathered in the interviews and the ongoing activities under the ATE Agenda provide robust validation of the identified trends for the Portuguese energy sector. These findings show that the commitment to decarbonization, the expansion and diversification of renewables, the electrification of end-use sectors, improvements in efficiency, infrastructure modernization, digitalization, and sustainable mobility are not just strategic projections but are already being operationalized and tested on the ground.

CHAPTER 4

Challenges on the Road to a Green Future

The energy sector in Portugal faces a set of significant barriers in its transition toward a more sustainable future. These barriers span technological, financial, regulatory, organizational, market, and socio-environmental dimensions, reflecting the complexity of the transformation process.



Limited technological maturity is one of the main obstacles. Solutions such as hydrogen production, biomass, offshore wind, carbon capture, and battery development are still at early stages in the country, reflecting restricted capacities. Concerns also arise regarding the availability and costs of raw materials for solar and wind, whose scarcity in global supply chains may affect adoption. Integrating these technologies into existing systems is complex, requiring data management across multiple actors, product scalability, and the completion of lengthy technical stages, from prototype development to platform creation.

Grid reliability, efficient operation, and the integration of new sources demand robust investments in generation capacity, grid expansion, and storage solutions. At present, the only viable large-scale option is pumped hydro storage, while the high capital costs and operational constraints of alternatives such as batteries and flywheels remain. E-mobility adds further pressure, with shortages in charging infrastructure and the adaptations required in the automotive industry. Growing digitalization also exposes the sector to cybersecurity risks, increasing vulnerability to attacks that may compromise data integrity and infrastructure security.

CHAPTER 4

Financial and economic barriers add further constraints. High investment costs represent a cross-cutting challenge: clean energy projects are capital-intensive, limiting the scope of public financing and hindering access for entrepreneurs and consumers. The higher price of electric vehicles compared to conventional ones makes them less accessible to several social groups. The initially low productivity of some renewable technologies constrains business development, while the potential devaluation of fossil assets can generate stranded assets, reducing available capital and making investors more cautious. This risk limits financing for renewable projects and is compounded by the cost-of-living crisis, which makes it harder for households to invest in efficient technologies or renewable energy solutions that require upfront costs, heightening the risk of energy poverty.

At the regulatory and political level, the Portuguese framework remains complex and challenging for new projects. Navigating multiple legal processes, permits, and certifications creates barriers to feasibility and licensing. Issues related to intellectual property, data protection, and confidentiality among partners are critical for collaboration and commercialization of solutions. Policy incoherence, driven by delays and political pressures, limits the ability to generate consistent long-term strategies. At the global level, geopolitical polarization hampers consensus on climate action and energy policies.

Organizational and operational limitations are also significant. The energy sector faces difficulties in attracting, retaining, and developing skilled professionals, as well as high turnover rates in product development areas. Coordination among diverse partners, particularly within the ATE Agenda, is hindered by bureaucracy, lack of calendar alignment, uneven data availability, and slow decision-making processes. Internally, organizations face obstacles in resource allocation, goal alignment, and project monitoring. Large companies encounter barriers in managing innovation, while new entrants have less capacity to generate and absorb knowledge.

In the market and business development sphere, the definition of viable business models remains a recurring barrier. Aligning technological advances with demand, accessing competitive markets, and identifying new business opportunities are essential. Market acceptance and trust are equally critical: some industrial clients remain skeptical of research projects, demanding concrete evidence of benefits to attract new customers and scale businesses. Partnership-building also presents challenges, including supplier integration and managing potential partners and competitors.

CHAPTER 4

Finally, socio-environmental barriers are also at play. Public and political resistance can hinder adoption, influenced by socio-urban disparities, shifts in consumption behavior, and low levels of awareness or participation. The impacts of climate change represent another critical factor: heatwaves, extreme weather events, natural disasters, and water scarcity directly affect renewable energy production, especially hydro, and infrastructure resilience.

Social inequalities further aggravate the problem, as low-income households and small businesses lack the financial resources to invest in sustainable solutions, risking exclusion and an uneven transition. At the same time, rising energy demand driven by population growth, urbanization, and the spread of energy-intensive technologies such as electric vehicles and data centers, adds pressure on existing systems and infrastructures, accelerating the need for the integration of new renewable sources.

CHAPTER 5

Towards a Just and Sustainable Transition: Key Strategies

The analysis of the documents makes it possible to identify strategic recommendations that point to a consistent pathway for transforming the Portuguese energy sector. First, there is a clear need to continue accelerating the adoption of renewable energies and investing in infrastructures that enable their efficient integration. Rising energy demand, driven by demographic growth, urbanization, and the electrification of transport and industry, requires responses that reconcile security of supply, sustainability, and efficiency.

The modernization of transmission and distribution grids plays a central role in this process. Smarter, digitalized networks capable of managing diverse energy flows are essential to ensure system reliability and integrate intermittent sources such as solar and wind. Linked to this modernization is the expansion of storage solutions, from pumped hydro to next-generation batteries, which are indispensable for stabilizing the grid and supporting electrification. At the same time, sustainable mobility must advance through the mass deployment of electric vehicles, the expansion of charging infrastructure, and the electrification of public transport, reducing reliance on fossil fuels and fostering new mobility models.

The energy transition does not end with technology: it also requires strong investment in human capital and more effective collaboration models. The development of new skills and the valorization of specialized human resources are indispensable conditions for absorbing and disseminating innovation. Likewise, greater coordination among companies, research centers, public entities, and local communities is necessary to reduce bureaucracy, align objectives, and ensure that innovation projects effectively reach the market. Trust in partnerships, data and intellectual property protection, and clarity in business models are critical factors to stimulate cooperation and create an environment conducive to investment.

CHAPTER 5

Another fundamental axis is the definition of public policies and a stable, coherent regulatory framework. Clear regulations, well-targeted incentives, and long-term strategies generate confidence among investors and companies while ensuring that the transition responds to societal needs. Regulation must be flexible enough to keep pace with innovation and robust enough to protect consumers and safeguard system security.

Finally, the energy transition must be conducted in an inclusive manner, ensuring that benefits reach all of society and that inequalities are not deepened. This implies developing mechanisms to support families and businesses with fewer financial resources to participate in the process, reducing social resistance, and ensuring that adaptation to climate change strengthens the resilience of infrastructures and communities.

The coherence between the ATE activities and Portugal's energy policy goals reinforces the strategic relevance of the initiative. The analysis shows that the ATE demonstrates strong alignment with the most encouraged national objectives, particularly in renewable energy integration, electrification, hydrogen development, energy efficiency, and sustainable mobility. This convergence reveals that the project's operational priorities are consistent with the country's long-term transition pathway, ensuring that technological innovation and system modernization effectively contribute to policy implementation and to the pursuit of a just and sustainable energy future.

Energy policy, regulation and strategy | The ATE policy goals endorsement

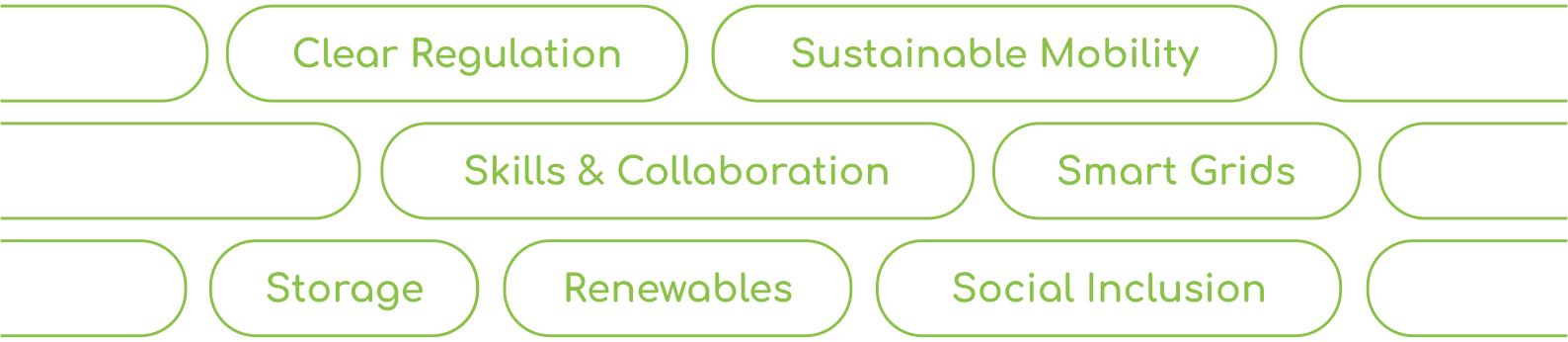
Based on the presented key policy document goals and ATE data, the figure below maps the ATE activities endorsement by levels, considering the primarily encouraged Portuguese strategies and goals

TRENDS	STRATEGIES & GOALS PRIMARILY ENCOURAGED
Renewable energies in economic activities	Use of renewable energy for electricity generation
	Use of renewables for heating
	Use of renewables for transportation
	Hydrogen production
	Green hydrogen consumption for transportation
	Green hydrogen consumption for industry
	Injection of green hydrogen into the gas grid
	Consumption of biofuels for transportation
	Creation of the biomethane market
	New biomass recovery plants
Electrification and source coupling	Share of electricity in total energy consumption
	Electricity distribution network
	Electricity capacity installed from PV and wind
	Hydrogen installed capacity in electrolysers
	Electricity consumption for transportation
	Electricity consumption for industry
	Battery storage capacity
Energy efficiency	Renovation of public buildings
	Saving energy in residences and buildings
Mobility	Number of electric vehicles
	Charging points

Figure: ATE policy endorsement levels by the primarily encouraged strategies and goals
Source: Developed by the authors from the ATE projects and subprojects data

CHAPTER 5

In summary, the recommendations converge toward an integrated strategy: accelerate renewables, modernize infrastructures, expand storage and sustainable mobility, invest in skills and collaboration, ensure clear and adaptive regulation, and promote a just and inclusive transition. Only in this way will it be possible to turn ambition into tangible results and position Portugal as a leading actor in the energy transition.



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DGEG, Direção Geral de Energia e Geologia. https://www.dgeg.gov.pt/

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ERSE, Entidade Reguladora dos Serviços Energéticos. https://www.erse.pt/inicio/

IEA, International Energy Agency. https://www.iea.org/

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