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The contribution of Renewable Energy Sources (RES) to the Greek economy

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ABSTRACT

This thesis explores how renewable energy sources (RES) shape Greece's economic performance, focusing on both their direct and indirect impacts on GDP, employment, trade balance, and regional development. RES have emerged as a major force behind Greece's economic growth and sustainable development, according to the study, which uses statistical data from ELSTAT, Eurostat, the Regulatory Authority for Energy (PAAEY), the Independent Power Transmission Operator (IPTO), the International Energy Agency (IEA), and the International Renewable Energy Agency (IRENA) for the years 2000–2025.

While their percentage of electricity generation surpassed 55% in 2023, above the EU average, the total installed RES capacity grew from 600 MW in 2000 to roughly 17 GW in 2024. A 1% increase in RES use results in a 0.13% increase in GDP, according to empirical research, while full implementation of the National Energy and Climate Plan (NECP) could increase Greek GDP by 2.5% by 2050. In addition, the energy sector's Gross Value Added (GVA) has increased dramatically, over 25,000 jobs have been created, and fuel imports have decreased from €9 billion in 2010 to less than €4 billion in 2024.

The findings demonstrate that RES is an essential component of social cohesion and sustainable growth. At the same time, the study highlights a number of lingering issues, including limited energy storage, inadequate grid capacity, and permitting delays. It also suggests policy measures to hasten the transition, such as boosting energy communities, integrating RES into the transportation and heating sectors, and expanding energy storage systems.

In conclusion, the findings show that renewable energy is not only an environmental goal but also a sound economic strategy for Greece, one that can boost long-term economic resilience, competitiveness, and energy security.

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LIST OF SYMBOLS

NECP: National Energy and Climate Plan

RES: Renewable Energy Sources

GDP: Gross Domestic Product

PAAEY: Regulatory Authority for Energy

IPTO: Independent Power Transmission Operator

HEDNO: Hellenic Electricity Distribution Network Operator

PV: Photovoltaic

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CHAPTER 1: Literature Review

1.1 Introduction

Energy policy has long been a decisive factor in shaping both economic growth and social welfare. The reliance of economies on fossil fuels (such as lignite, oil, and natural gas) has spurred rapid industrial growth and increased output, while also giving rise to significant environmental and societal issues. Climate change, air pollution, dependency on energy imports, and volatility in global oil prices underscore the necessity for a shift towards a new, sustainable energy framework. In this scenario, Renewable Energy Sources (RES) take on a vital role. Their advancement is promoted globally as an essential factor for achieving energy security, lowering greenhouse gas emissions, and ensuring a sustainable development model. The European Union has implemented a set of mandatory targets (20-20-20, Fit for 55, Green Deal) that prioritize the growth of renewable energy sources (RES) in overall energy consumption as a central component of the strategy for achieving climate neutrality by 2050.

As a member of the European Union, Greece has committed to these objectives by implementing the National Energy and Climate Plan (NECP), which aims to increase the role of renewable energy sources (RES) in its energy mix. Despite facing economic structural challenges, Greece boasts abundant wind and solar resources, notable hydroelectric capacity, and potential for biomass and geothermal development. This combination of natural resources and international obligations positions Greece as a compelling case study for examining the impact of RES on the economy.

The economic aspect of renewable energy sources (RES) is emphasized in several ways. Firstly, it creates new investment opportunities and job prospects in the areas of installation, maintenance, and operation of energy projects. Secondly, it decreases the country's reliance on imported fuels, which enhances the trade balance and bolsters energy security. Additionally, the financial contributions made to local communities, as exemplified by the "Special RES Fee" allocated to municipalities and consumers, demonstrate that the advancement of RES is closely associated with regional development and social cohesion.

Research from both international and domestic sources illustrates that the connection between energy consumption and economic growth is complex. Studies conducted by Ntanos et al. (2018) reveal a positive long-term relationship between the consumption of renewable energy sources (RES) and GDP within Europe, while Pegkas (2019) identifies that, in Greece, both RES and fossil fuels contribute positively to economic growth, given that RES are included in a sustainable transition strategy. In a similar vein, Stamopoulos et al. (2021) emphasize that the execution of the National Energy and Climate Plan (NECP) can enhance GDP and employment, creating a multiplying effect on Greece's economy. In conclusion, this introduction to the subject underscores that RES represent not only an environmental goal but also a viable development strategy with significant economic repercussions. Therefore, it is crucial to research their economic impact on Greece in order to comprehend the existing state of affairs and to develop future policies that would support the green transition.

1.2 Aim of the study

This thesis looks into and examines how Renewable Energy Sources (RES) contribute to the Greek economy, focusing on both the big picture economic effects and the smaller, individual impacts. In a time when there's a strong push to reduce carbon emissions, rising global energy costs, and growing concerns about climate change, expanding renewable energy is not just important for the environment but also a smart move for ensuring the country's long-term economic stability.

The study aims to record, evaluate, and understand how renewable energy sources contribute to the country's GDP, create jobs, improve the trade balance by reducing fuel imports, and support both the national and local governments financially. It also looks at how renewable energy helps make the Greek economy more competitive by attracting investments, encouraging technological advances, and promoting new business ideas. The choice of Greece as a case study is of particular interest, as the country combines:

• high dependence on fossil fuel imports,

• rich potential in solar and wind energy,

• significant structural weaknesses in the operation of the energy sector (bureaucracy, limited social acceptance), and

• increased needs for economic growth and stability after a decade of economic crisis.

So, the study aims to add valuable insights to existing research by carefully examining the connection between energy and economics, offering helpful findings for scholars, government officials, and those who invest in energy projects.

1.2.1 Questions

In order to achieve the above objectives, the thesis seeks to answer a series of research questions that are the guide of the analysis:

1. What has been the development course of RES in Greece over the last two decades and what factors influence it?
2. To what extent has the penetration of renewables contributed to GDP growth and employment growth?
3. How do renewables affect the country's trade balance, given the high dependence on imported fuels?
4. What are the direct and indirect fiscal effects of the development of RES (tax revenues, special RES tax, aid to municipalities and consumers)?
5. What challenges (institutional, social, technological) are inhibiting factors for their further exploitation?

1.3 Definition and categories of RES (wind, solar, hydroelectric, biomass, geothermal).

Renewable Energy Sources, or RES, are types of energy that come from natural resources which are always being replenished by nature. Using these sources doesn't run them out, unlike fuels like coal, oil, and natural gas. The European Union's Directive 2009/28/EC says that RES include wind, sunlight, water power, plants and plant-based fuels, and heat from the earth. These sources are from natural things that never run out and have a much smaller effect on the environment than traditional fuels.

1.3.1. Wind power

Wind energy uses the power of moving air, which is captured by wind turbines to generate electricity. Greece has some of the best wind resources in Europe, especially in the Aegean Sea, where the average wind speed is more than 7.5 meters per second each year. Wind power is the main type of renewable energy used in the country, and by 2023, the total amount of wind power generation capacity had gone beyond 5 gigawatts (Regulatory Authority for Energy, 2024).

1.3.2. Solar energy

Solar energy comes in two main types: photovoltaic systems, which turn sunlight into electricity, and solar thermal systems, which use sunlight to create heat. Greece gets more than 2,800 hours of sunshine each year, making it one of the sunniest places in Europe, according to Manolopoulos et al. (2016). In 2024, the total amount of solar panels installed in Greece reached over 9 gigawatts, which helped provide around 21% of the country's electricity.

1.3.3. Hydropower

Hydropower uses the movement of water to create electricity. In Greece, big hydroelectric plants, mostly located in Western Macedonia, Epirus, and Central Greece, help supply electricity to the national grid. These plants also serve as backup power sources and can store energy (Zafirakis et al., 2013). Although large hydropower projects have been around for a long time, there isn't much room left for new developments, unlike smaller hydro projects

1.3.4. Biomass and Bioenergy

Biomass is a type of energy made from living things like plants and animals. It can be used to create energy by burning it or through other methods, such as making biogas. In Greece, biomass isn't used a lot right now compared to other energy sources, but there's a lot of room for it to grow, especially in farming and using things that are thrown away. (Zafirakis, Chalvatzis & Kaldellis, 2013).

1.3.5. Geothermal

Geothermal energy uses heat from inside the Earth. In Greece, there are many areas with lots of geothermal heat, especially in the northern parts like Evros, Samothrace, Samos, and Nisyros. However, using this heat isn't very common because of problems with rules, technology, and society. On the other hand, low-enthalpy geothermal energy is used for things like growing plants in greenhouses, heating homes, and other heat-based activities.

1.4 Global framework for Renewable Energy Sources (RES) – EU policies, Green Deal, sustainable development goals (SDGs).

The establishment of Renewable Energy Sources (RES) cannot be viewed in isolation from the political and institutional framework, as their trajectory is significantly influenced by both national and international strategies. The transition to cleaner energy is interconnected with the worldwide initiative to combat climate change and the imperative to decarbonize economies.

International and European Policies

The European Union has been at the forefront of advocating for the green transition. The initial set of objectives, known as '20-20-20', was outlined in 2007 and was to be achieved by 2020:

- A 20% reduction in greenhouse gas emissions,
- A 20% increase in the share of RES in final energy consumption,
- A 20% improvement in energy efficiency.

This was succeeded by Directive 2009/28/EC, which established binding goals for each member state. For Greece, the target was set at an 18% share of RES in final energy consumption by 2020, a goal that was ultimately reached largely due to the swift rise in photovoltaic installations following 2010 (Pegkas, 2019).

The new Fit for 55 strategy (2021) introduces even more ambitious goals:

- A 55% reduction in emissions by 2030,
- A minimum 40% share of renewables in final energy consumption across the EU.

Ultimately, the European Green Deal (2019) outlines the vision for achieving a climate-neutral Europe by 2050, with Greece pledging to fully decarbonize its electricity sector by 2035.

The Greek Institutional Framework

The evolution of renewables in Greece has been influenced by a series of legislative measures:

- Law 1559/1985: it was the first legislation to permit small-scale energy production from RES.
- Law 2244/1994: it introduced the initial incentives, featuring fixed feed-in tariffs for energy produced from RES.
- Law 2773/1999: this law aligned the Greek framework with Directive 96/92/EC, thereby establishing regulatory authorities (PAAEY) and guaranteeing priority access for RES to the grid.
- Law 3468/2006: it revised the support system to offer higher feed-in tariffs and streamlined licensing processes.

- Law 3851/2010: this law transposed Directive 2009/28/EC, instituting a national target of 20% RES in final energy consumption and 40% in electricity generation by 2020.
- Law 4414/2016: it replaced the fixed price model with a competitive support mechanism through tenders (feed-in premium), aligning Greece with the new European competitive market framework.

Financial Mechanisms and the Social Dimension

The growth of RES has been greatly aided by both European and national financial mechanisms (NSRF, Horizon 2020, InvestEU). Simultaneously, the Special RES Tax (3% of project turnover) was implemented, which is allocated to local municipalities and consumers, serving as a tool for fostering social acceptance. In 2023, this tax generated over €35 million for municipalities and households in regions with wind and hydroelectric projects.

The national and international institutional framework has played a critical role in advancing RES in Greece. Despite the country's considerable natural resources, the advancement of the green transition has heavily relied on legislation, support systems, and European directives. Nonetheless, challenges such as bureaucratic hurdles, community acceptance, and the necessity for modernized networks persist, which will be central issues in the years to come (Manolopoulos et al., 2016; Zafirakis et al., 2013).

1.5 Energy – economic development relationship in theory (energy economics, dependency theories).

For many years, there has been a great deal of study and policy discussion about the connection between economic growth and energy use. In addition to capital and labor, energy is seen as a crucial component of production, and its availability has a direct impact on an economy's competitiveness and productivity (Apergis & Payne, 2010). RES is a wise decision for sustainable growth because an excessive reliance on fossil fuels poses threats to the economy and the environment.

Theoretical Approaches

In the international literature, four basic hypotheses have been developed on the relationship between energy and economic development (Ozturk, 2010):

1. **Growth hypothesis**: energy consumption leads to economic growth.

2. **Conservation hypothesis**: economic growth determines energy consumption.
3. **Neutrality hypothesis**: there is no causal relationship between the two.
4. **Feedback hypothesis**: there is a two-way relationship between energy and growth.

These hypotheses are of particular interest in the case of RES, as they combine economic and environmental benefits.

Empirical Findings for Greece

The body of research on the connection between Greece's economic growth and Renewable Energy Sources (RES) is extensive and multifaceted, highlighting different but related facets of the same issue. Although researchers concur that renewable energy sources (RES) have a positive impact on GDP and economic growth, the extent of this contribution varies depending on the institutional framework's stability and efficacy, the degree of RES penetration, and the degree of societal acceptance of energy policy.

Both RES and conventional fuels have a beneficial and statistically significant long-term impact on Greek economic growth, according to Pegkas' (2019) study, which covered the years 1990–2016. Specifically, it reveals that a 1% increase in RES energy use translates into a roughly 0.13% GDP gain, while a corresponding increase in fossil fuel use yields a roughly 0.22% GDP gain. This research shows that even while RES are beneficial, the Greek economy is still greatly impacted by the use of conventional fuels, underscoring the necessity of a slow but continuous transition away from fossil fuels. Similar results were found in the study by Ntanos et al. (2018), which looked at 25 EU member states from 2007 to 2016 and concluded that RES consumption and economic growth are positively correlated, with the effect being bigger in nations with higher GDP levels. According to these findings, more developed nations are better able to absorb investments in clean technologies and benefit more from the shift to a sustainable energy system. This is directly related to Greek reality, where the dynamics of RES investments are significantly influenced by the availability of capital and expertise.

A critical dimension was recently added to the pertinent discussion by Dritsaki et al. (2024), who showed that whereas the use of fossil fuels has a negative impact on economic growth, higher RES penetration has a favorable long-term effect on GDP. This finding deviates from previous research, such Pegkas (2019), which affirmed the complementary benefits of both conventional and renewable energy sources. It also shows how the Greek economy has been gradually moving toward cleaner energy sources. Internationally, same patterns are also evident, with rising investments in renewable energy sources being correlated with lower emissions, job development, and improved energy security.

Applied assessments of multiplier effects also demonstrate the beneficial impact of RES on the Greek economy. Using an input-output analysis within the framework of the National Energy and Climate Plan (NESK), Stamopoulos et al. (2021) calculated that investments in RES may create thousands of new employment and boost Greek GDP by about 2.5% by 2050. According to their analysis, these investments boost domestic demand, employment, and public income, making them not only an environmentally friendly decision but also a growth lever with a significant social impact. Furthermore, the quick adoption of renewable energy sources (RES), electrical connections, and compensation programs (like the Energy Transition Fund) strengthen Greece's economy's resilience, lessen reliance on imported fossil fuels, and protect households' and businesses' competitiveness from changes in global energy prices, according to the IEA's energy policy review (2023).

Even with the favorable outcomes, switching to a sustainable energy system is not a given. Zafirakis, Chalvatzis, and Kaldellis (2013) emphasized the significance of socially equitable support mechanisms, including targeted subsidies and feed-in tariffs, pointing out that the balance between investment costs and social benefits determines the true economic efficiency of RES. For their part, Manolopoulos et al. (2016) emphasized the institutional and social barriers—such as bureaucracy, the unpredictability of the regulatory environment, and the low level of social acceptance of specific technologies—that prevented RES from developing more quickly in Greece. These barriers hindered the full utilization of RES's beneficial economic effects and slowed down their adoption in the energy mix. However, public opinion surveys like those conducted by Ntanos et al. (2018) and Tsiaras et al. (2025) reveal that local communities' acceptance of RES is primarily dependent on the amount of information available, their level of trust in institutions, and the equitable distribution of benefits.

The economic impact of renewable energy sources (RES) extends beyond just macroeconomic metrics. Greek law mandates a Special RES Fee of 3% on the revenues of projects, which is primarily reinvested in local communities. In 2023, this fee generated a total of 35 million euros, with 14.2 million euros allocated directly to lowering household electricity costs, and the remaining 21.2 million euros distributed to the municipalities where RES facilities are located. Notably, 82% of this revenue came from wind energy, highlighting its crucial role in the regional redistribution of funds and the enhancement of local economic activity. In this regard, Greek academic research exploring the link between RES and development is also significant. Stoimenidis (2009) in his doctoral research examined the connection between renewable energy sources (RES) and regional development, emphasizing how investments in clean energy can serve as catalysts for growth in rural and island regions. Maniatis (2020) explored the effects of RES integration on electricity tariffs, documenting the “merit-order effect” within the Greek electricity market from 2012 to 2018, which refers to the decrease in wholesale price resulting from the addition of low-marginal-cost renewable sources. Kosteletos (2020) concentrated on the economic and social aspects of RES advancement in Greece, stressing the importance of enhancing the institutional framework and encouraging citizen engagement. Davanelos (2022) noted local residents' perspectives on RES and sustainable development, discovering that acceptance tends to rise when community members recognize direct benefits for their area. Likewise, postgraduate studies from the National Technical University of Athens, which examined energy independence for islands such as Astypalaia and clean energy scenarios, underscore the significance of RES as a driver of regional development and energy self-sufficiency.

The overall assessment of Greece indicates that renewable energy sources (RES) positively impact economic development and job creation while reducing the nation's energy reliance. However, the degree of this impact depends on factors such as the penetration rate, the effectiveness of political incentives, social acceptance, and the quality of institutional support systems. With considerable renewable resources available – including solar, wind, geothermal, and hydroelectric energy – Greece finds itself at a pivotal moment: advancing the energy transition will shape not only its energy strategy but also its broader development trajectory in the upcoming decades. If utilized wisely, RES can serve as a cornerstone of a new developmental framework focused on a sustainable economy, energy democracy, and an equitable transition for society.

The trajectory of renewable energy policy in Greece to date reflects a clear convergence towards European targets, but also persistent weaknesses in its implementation. The transition from fixed feed-in tariffs to competitive offers with feed-in premiums has improved fiscal efficiency and reduced excessive subsidies of the previous decade. However, delays in licensing, grid constraints and insufficient storage resources limit the benefits of the rapid reduction in technology costs. While the NECP is characterised by coherence of objectives during the design phase, an “implementation gap” remains evident: the institutional framework is often revised in a piecemeal manner and location and social acceptance issues are not sufficiently integrated during the initial design phase. Consequently, the effectiveness of Greek policy is considered satisfactory in the conception phase, but moderate in implementation, and the acceleration of public procedures is a key prerequisite for success.

Greece still has difficulties implementing the Fit for 55 targets in comparison to other EU members, notwithstanding the advancements. The transition process is frequently slowed down by social resistance, grid saturation, and bureaucratic delays. In contrast to nations like Portugal or Denmark, Greece has not yet established adequate cross-border connections and energy storage capacity, both of which are necessary to fully realize its renewable potential.

CHAPTER 2: Energy Policy in Greece

2.1 Historical evolution of the energy mix in Greece

The transformation of the Greek energy system over recent decades illustrates the gradual shift from a heavy reliance on fossil fuels toward a more varied and sustainable energy foundation. Up until the 1990s, lignite served as the primary source of electricity generation, allowing the country to achieve energy self-sufficiency due to its abundant domestic resources. The output from lignite power plants accounted for over 70% of the overall electricity supply, making this resource the "foundation" of Greece's energy framework (Zafirakis, Chalvatzis & Kaldellis, 2013).

Simultaneously, a notable proportion was fulfilled by oil imports, particularly in the transportation sector and for operating independent island systems. Historically, Greece's reliance on imported oil has been significantly high, raising the economy's vulnerability to fluctuations in international prices (Manolopoulos et al., 2016).

The first major diversification of the energy mix took place after 1996, when natural gas was introduced as a fuel for electricity generation. The creation of pipelines and infrastructure primarily supported Attica and Northern Greece, somewhat diminishing the single-minded reliance on lignite and oil. Nevertheless, as a fuel that is also imported, natural gas did not completely address the challenge of energy dependence, yet it provided meaningful environmental advantages by gradually replacing more polluting lignite plants.

In the early 2000s, Renewable Energy Sources (RES) started to gain momentum, particularly through wind and solar power. The establishment of policy incentives, such as feed-in tariffs (Law 2244/1994, Law 3468/2006), attracted private sector investment, enabling the swift growth of RES projects. Notably, the period between 2008 and 2013 witnessed a dramatic increase in photovoltaic installations, driven by generous electricity purchase rates. Consequently, Greece emerged as one of the European countries with the highest levels of solar energy integration (Ntanos et al., 2018).

Although the economic crisis post-2010 temporarily slowed investment activity, it could not deter the continued growth of renewables, which gradually affirmed their position in the energy landscape. Starting in 2015, energy policy shifted its focus toward decarbonization, with Greece pledging to completely phase out lignite plants by 2028. In

2019, an initiative to expedite this process was formally unveiled, marking a significant change in the national energy mix.

Presently, Greece's energy system is defined by the increasing role of renewables, a decline in lignite use, and an enhanced position of natural gas as a "transition" fuel. This historical evolution reflects both international demands for decarbonization and the domestic necessity to diversify the energy portfolio to bolster energy security and the sustainability of the Greek economy.

2.2 Legislative and institutional framework for RES (e.g. Law 3851/2010, National Energy & Climate Plan)

Greece's energy sector is undergoing a swift transformation, characterized by a notable rise in the adoption of Renewable Energy Sources (RES), the fast-tracking of the phase-out of lignite, and the concurrent bolstering of natural gas as a transitional fuel. This progress is associated with both European obligations and the implementation of national policies that have fostered the development of new RES initiatives (European Commission, 2019).

As reported by Eurostat and the Regulatory Authority for Energy (PAAEY), in 2023, renewable energy sources accounted for approximately 55% of final electricity demand in the interconnected system, positioning Greece among the EU countries with the highest participation of RES (Greek News Agenda, 2025). This figure significantly surpasses the 40% goal established for 2020, underscoring the effectiveness of the regulatory framework and the intensified investment activity over the past decade.

<u>Installed Power and Technologies Allocation</u>

The total capacity of renewable energy sources (RES) is projected to have reached 17 GW by 2024, whereas the National Energy and Climate Plan (NECP) forecasts that this capacity will increase to 28 GW by 2030 (Stamopoulos et al., 2021).

<u>Economic and Social Impacts</u>

The advancement of renewable energy sources (RES) has considerable economic and social repercussions. A prime illustration is the Special RES Tax, which is set at 3% of project turnover and is allocated to local municipalities and consumers. In 2023, this assistance totaled €35 million, with €14.2 million directed towards lowering electricity bills and €21.2 million provided as financial aid to municipalities (ELETAEN, 2024). This allocation demonstrates that renewable energy not only enhances energy security and environmental safeguarding but also fosters social unity and bolsters local development.

The current situation of the Greek energy system indicates that the nation is undergoing a swift energy transformation. The growing share of renewables within the energy mix, alongside the reduction of lignite usage, underscores the critical importance of both the institutional framework and investment efforts. However, to meet the objectives for 2030 and 2050, there is a need for further enhancements of the electrical grids, advancements in energy storage solutions, and the establishment of a stable investment climate.

2.3 Role of the bodies (PAAEY, DAPEEP, HEDNO, ADMIE)

The progress of Renewable Energy Sources (RES) in Greece is significantly influenced by the institutional and regulatory framework, which establishes the market's operational conditions and affects the investment landscape. The gradual alignment of national laws with European directives has played a crucial role in boosting the adoption of RES and creating a more competitive energy sector (Manolopoulos et al., 2016).

Greek legislation includes a number of important interventions that have contributed to the promotion of RES:

- Law 1559/1985: the right of private individuals to produce electricity from RES on a small scale was established.
- Law 2244/1994: introduced the first fixed feed-in tariffs (FiTs), enhancing the economic viability of investments in RES.
- Law 2773/1999: transposed Directive 96/92/EC, paved the way for the liberalization of the electricity market and provided for the creation of the Regulatory Authority for Energy (PAAEY).
- Law 3468/2006: improved the support regime with higher FiTs and simpler permitting procedures, which significantly boosted the first large investments in wind and photovoltaic projects (Zafirakis, Chalvatzis & Kaldellis, 2013).
- Law 3851/2010: transposed Directive 2009/28/EC, increased the national targets for the participation of RES to 20% of final energy consumption and to 40% of electricity production by 2020 (Pegkas, 2019).

- Law 4414/2016: introduced competitive support mechanisms through tenders and premium feed-in, replacing the previous FiTs regime, in accordance with European competition policy.
- Law 4685/2020: significantly simplified the licensing procedures, introducing the "producer certificate" and reducing the implementation time of investments.

The above laws formed the institutional background that allowed Greece to significantly increase the share of renewables in its energy mix.

Institutional Bodies

The operation of the electricity market is based on specialized institutions:

- Regulatory Authority for Energy (PAAEY): an independent authority responsible for regulating and supervising the electricity and natural gas market.
- IPTO (Independent Power Transmission Operator): manages the high voltage transmission system and ensures its safe operation.
- HEDNO (Hellenic Electricity Distribution Network Operator): responsible for the medium and low voltage network, as well as for the connection of small RES projects.
- DAPEEP (RES and Guarantees of Origin Operator): manages the finances of RES projects, the payments of producers and the guarantees of origin of "green" energy.

These institutions ensure market stability and transparency, which are essential for attracting investment.

Relationship with European Policy

The Greek institutional framework aligns closely with the European Energy and Climate Strategy. The first binding targets for 2020 were established by Directive 2009/28/EC, while Directive (EU) 2018/2001 and the Fit for 55 package introduced new enhanced requirements, aiming for at least 40% contribution of RES in final energy consumption by 2030 (European Commission, 2019, 2021). The National Energy and Climate Plan (NECP) serves as the primary instrument for fulfilling these commitments, aiming for an installed RES capacity of 28 GW by 2030 and complete decarbonization by 2050. The advancement of the energy sector's institutional framework in Greece has been crucial for the growth of RES. By implementing support mechanisms, gradually liberalizing the market, and aligning with European guidelines, a stable environment was established, facilitating a notable increase in RES participation within the national energy mix.

However, issues related to complicated processes, outdated networks, and social acceptance persist, which must be resolved to meet the national and European objectives set for 2030 and 2050.

2.4 Targets until 2030–2050 (climate neutrality)

Greece's energy strategy for the coming decades is part of the broader framework of the European Green Deal and the Fit for 55 package, which set climate neutrality by 2050 as a key goal. Greece, as a member state of the European Union, has adopted ambitious targets through the National Energy and Climate Plan (NECP), which provide for a radical restructuring of the energy system based on Renewable Energy Sources (Ministry of Environment and Energy, 2019).

2030 targets

Based on the NECP, by 2030 it is expected:

- Total installed RES capacity: at least 28 GW.
- Participation of RES in electricity production: ~65%.
- Reduction of CO_2 emissions: by 55% compared to 2005 levels, in full alignment with the Fit for 55 package (European Commission, 2021).
- Lignite phase-out: complete shutdown of lignite plants by 2028 at the latest.
- Strengthening energy interconnections: completion of projects that will allow the full electrical interconnection of the Aegean islands by 2030 (Reuters, 2024).

<u>Targets for 2050</u>

In the long run, Greece aims for full climate neutrality — a complete transition to a zero-emission energy system that will redefine its production model and global standing:

- Participation of RES in the energy mix: >90%, with an emphasis on wind (including offshore projects) and photovoltaics.
- Energy storage: development of large storage infrastructure (batteries, pumped storage) to balance increased production from RES.
- Hydrogen and new technologies: harnessing green hydrogen as a fuel for industry and transport, combined with carbon capture and storage technologies (IEA, 2022).
- Energy self-sufficiency: reducing dependence on imported fuels, with the aim of enhancing security of supply and Greece's role as an energy transit hub in Southeastern Europe (Greek News Agenda, 2025).

The objectives outlined for the years 2030 and 2050 demonstrate the nation's commitment to completely overhauling its energy model. The success of these objectives will hinge on the ability to execute large-scale renewable energy and storage projects, upgrade transmission and distribution networks, incorporate innovative technologies, and gain social support for the energy transition. Achieving these targets presents not only an environmental challenge but also a chance to boost the competitiveness and sustainable development of the Greek economy.

An analysis of the Greek energy system has indicated a significant shift from reliance on lignite and imported fossil fuels toward an emphasis on Renewable Energy Sources (RES). A historical overview underscores the importance of lignite as a key component of electricity generation for many years, while developments over the past two decades have highlighted the rapid integration of renewables into the energy mix, alongside the adoption of natural gas as a transition fuel.

As of 2023, more than half of the final electricity consumption is attributed to RES, illustrating the success of the regulatory framework and investment initiatives. Concurrently, the system is further bolstered by socio-economic mechanisms, such as the Special RES Tax, which empowers local communities and fosters acceptance of the energy transition.

The progress of the regulatory framework has been crucial, as the establishment of support mechanisms, market liberalization, and alignment with European policies have created a stable environment conducive to the rapid growth of RES. Nevertheless, important challenges persist, including the need to modernize networks, accelerate permitting processes, and secure broad social acceptance.

The strategic objectives established for 2030 and 2050 embody the aspiration for an economy with zero emissions and energy independence. Reaching these goals necessitates a blend of financial investment, institutional changes, and technological advancements. The following chapter will specifically highlight the progress of renewable energy sources (RES) in Greece, focusing on the growth of installed capacity, the distribution of technologies, and regional variations—all of which will serve as the foundation for analyzing their economic impact.

An international comparison reveals two contrasting images for Greece. On the one hand, the share of renewables in electricity generation is relatively high, approaching the European “core” (Portugal, Spain, Denmark). On the other hand, progress in heating/cooling and transport lags significantly, differentiating Greece from countries with advanced storage systems, interconnections and end-user electrification. Portugal has achieved acceleration thanks to a single digital licensing portal and a transparent storage framework, Spain has supported self-generation/storage with a stable regulatory horizon and Denmark has adopted a long-term strategy for the development of offshore wind and strong interconnections. Therefore, Greece needs faster and predictable procedures, targeted incentives for storage and rapid integration of energy communities into local markets.

The NECP offers a thorough road map, but successful execution is essential to its success. Greece's present course is in line with EU 2030 ambitions, but the nation needs to do a better job of integrating RES in the transportation, industrial, and heating sectors. Faster licensing and digitization processes can significantly increase investment attractiveness and policy efficacy, as demonstrated by a comparison with Spain and Portugal.

In contrast to the “Fit for 55” strategy, electricity generation in Greece is on track to achieve its medium-term goals, but success by 2030 requires three key accelerators: (a) grid availability and smart congestion management, (b) the development of storage as “system infrastructure” rather than as an occasional investment, and (c) a socially fair policy for electrification of end-users (heat pumps, electromobility). The NECP sets clear quantitative targets, but monitoring progress should be linked to binding intermediate indicators (e.g., number of GWh of stored energy in operation, time to issue permits for each milestone, local acceptance rates). Formal compliance is not enough. “Operational compliance” is required, which translates into real energy on the grid, minimizing congestion and maximizing local added value.

CHAPTER 3: Economic Contribution of RES

3.1 Introduction

The progress of Renewable Energy Sources (RES) is essential not just for environmental reasons but also as a catalyst for economic development. The economic impact of renewables can be examined on several fronts, including the immediate boost to Gross Domestic Product (GDP) resulting from investments and energy production, as well as their indirect ramifications on employment, tax income, and regional advancement, alongside broader economic implications in establishing a new growth paradigm (Stamopoulos et al., 2021).

Research consistently emphasizes the significance of RES for economic stability. Pegkas (2019) identified a positive and statistically meaningful relationship between energy consumption from RES and Greek GDP, while Dritsaki et al. (2024) showed that replacing fossil fuels with RES fosters sustainable growth over the long term. Concurrently, Ntanos et al. (2018) pointed out that the impact of RES is more pronounced in nations with higher levels of economic development, highlighting the vital role of investment and regulatory frameworks.

In Greece, the economic role of RES is closely associated with the transition away from lignite and the pursuit of energy independence. Substituting lignite with RES not only helps decrease emissions but also reduces reliance on imported fuels, thereby enhancing the trade balance. Furthermore, the implementation of the Special RES Tax (3% of project revenue) directly benefits local communities by providing income and fostering development (ELETAEN, 2024).

Consequently, examining the economic impact of RES in Greece is essential not only for evaluating past performance but also for developing strategies that will maximize future advantages. The subsequent sections will explore both the direct and indirect impacts of RES on GDP, their broader economic consequences, and a case study illustrating their significance in the Greek economy as reflected in international research.

3.2 Direct contribution to GDP

The direct impact of Renewable Energy Sources (RES) on the Gross Domestic Product (GDP) is connected to the investments made in developing and implementing projects, the generation and sale of electricity, as well as the job creation within the industry.

Unlike other energy sources that rely on imported fuels, RES harness local natural resources (such as wind, solar, water, biomass, and geothermal), resulting in the majority of the economic value being retained within the country (Manolopoulos et al., 2016).

3.2.1 Investments in RES projects

The advancement of renewable energy source (RES) projects necessitates considerable financial resources from both private and public sectors. The National Energy and Climate Plan (NECP) indicates that around €43 billion will be required for Greece's green transition by 2030 (Ministry of Environment and Energy, 2019). Over the past decade, more than €9.5 billion has already been allocated to wind and solar initiatives, as well as related infrastructures, significantly contributing to GDP growth (Greek News Agenda, 2025).

The establishment of substantial solar and wind energy facilities, including those in Western Macedonia and South Evia, has resulted in considerable local investments in engineering, materials, and services. These investments directly influence GDP by generating demand in industries such as construction, transportation, engineering, and the provision of specialized technical services (Zafirakis et al., 2013).

3.2.2 Electricity production

The generation of electricity from renewable energy sources (RES) provides stable income for the economy, as RES installations are compensated through electricity sales or traditional support mechanisms such as feed-in tariffs, feed-in premiums, and tenders. As reported by DAPEEP, in 2023, the energy generated from RES surpassed 25 TWh, more than doubling the figures from 2010. This production accounts for a substantial portion of local consumption, reducing expensive fuel imports and enhancing domestic value creation. Economic evaluations of energy generation reveal that renewables contribute over €6 billion annually to GDP through the gross value added they generate (Greek News Agenda, 2025).

3.2.3 Job creation

The establishment and functioning of renewable energy sources (RES) projects play a significant role in generating thousands of jobs across the country. As reported by IRENA (2022), each megawatt (MW) of RES capacity installed results in an average of 3–5 jobs being created during the construction phase, along with 1–2 jobs for ongoing operation and maintenance. With Greece's installed RES capacity reaching around 17 GW in 2024, it is anticipated that renewables are directly responsible for supporting over 25,000 jobs. These jobs span a diverse array of fields – from engineers and technicians at plants to legal professionals and financial consultants – thereby enhancing not just the energy industry but also a variety of highly skilled occupations. According to Stamopoulos et al. (2021), the comprehensive execution of the National Energy and Climate Plan (NECP) has the potential to generate tens of thousands of additional jobs, particularly in areas impacted by the transition away from lignite, such as Western Macedonia.

3.2.4 Improving trade balance

The replacement of imported fossil fuels with domestic renewable energy sources results in an immediate enhancement of the trade balance. Greece has historically allocated considerable resources to the import of oil and gas, negatively impacting the current account balance. The growing adoption of renewable energy diminishes these imports, thereby strengthening the nation’s overall economic position (Dritsaki et al., 2024).

3.3 Indirect contribution

Moreover, alongside the direct impact of Renewable Energy Sources (RES) on GDP via investments and electricity generation, the associated indirect benefits—such as job creation, increased tax income, decreased reliance on fuel imports, and the encouragement of local economies—hold significant value. These advantages contribute to regional development, foster public support for the energy transition, and enhance the overall macroeconomic stability of the nation.

Investment in RES leads to tax income both during the construction period (through VAT, various fees, and contractual agreements) and throughout the operational phase (corporate tax, insurance contributions from employees, and local taxes). The research conducted by Ntanos et al. (2018) indicated that utilizing energy from RES corresponds with greater fiscal stability in EU nations, by bolstering the tax base. Revenue generated from the RES sector has consistently risen over the past ten years, particularly following the swift adoption of photovoltaic technology.

One of the most typical forms of indirect contribution is the Special RES Tax, which is paid to local communities and consumers. This fee corresponds to 3% of the annual turnover of RES projects and is divided into two directions:

- **Municipalities**: to finance local development projects.
- **Consumers**: to reduce electricity bills.

In 2023, a total of €35 million was distributed through the RES Special Tax, with €14.2 million allocated for lowering electricity bills for households and €21.2 million directed towards local municipalities (ELETAEN, 2024). For example, the Municipality of Karystos in Evia received more than €5.4 million, while the Municipality of Thebes was allocated around €2.8 million, which were aimed at local investments and enhancing social infrastructure.

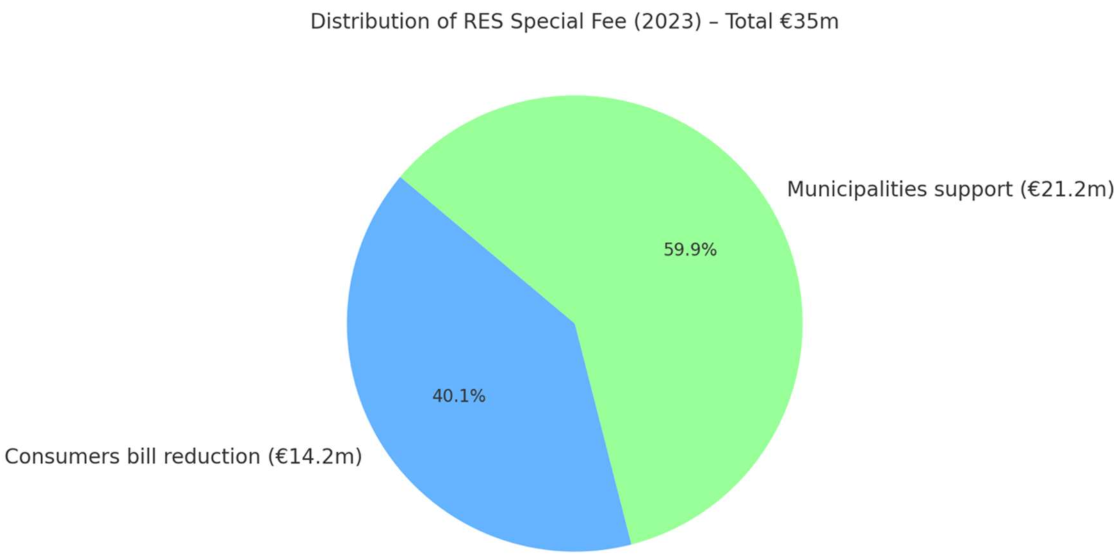

Figure 1: Allocation of the Special RES Fee (2023) - The allocation of the Special RES Fee for the year 2023, totaling 35 million euros, shows that 59.9% was allocated to municipalities to support local development and social infrastructure, while 40.1% was used to reduce consumers' electricity bills. This mechanism contributes to strengthening the social acceptance of RES and to the redistribution of the benefits of green energy to local communities (Source: ELETAEN, 2024; Zafirakis et al., 2013).

This illustration depicts how the Special RES Tax is proportionally shared between consumers and local governments. This framework guarantees that the advantages of RES initiatives are evenly allocated to nearby communities, encouraging social acceptance (Zafirakis et al., 2013). The rise in electricity production from RES significantly lessens the reliance on oil and natural gas imports, which have traditionally been a major strain on Greece’s trade balance. As noted by Dritsaki et al. (2024), replacing imported fuels with locally produced energy helps diminish the external deficit and enhances the country's competitive edge. Beyond the direct employment opportunities generated during the building and running of these projects, the creation of indirect jobs in related fields such as transportation, construction, service delivery, and material supply is equally crucial.

The IRENA study (2022) indicates that the advancement of RES generates a substantial multiplier effect on jobs by boosting demand in multiple sectors of the economy. The indirect impact of renewables on GDP is especially significant, as it connects the green transition with regional growth, social unity, and financial support. Mechanisms like the Special Renewable Energy Tax ensure that green energy serves not only as an ecological alternative but also as a catalyst for socio-economic progress.

3.4 Macroeconomic effects

The role of Renewable Energy Sources (RES) in the Greek economy goes beyond the direct and indirect advantages mentioned earlier. On a macroeconomic scale, renewable energies influence the overall growth patterns of the country, improve macroeconomic stability, and foster an opportunity for a new production model centered on sustainable development. These effects primarily relate to four aspects: economic growth, trade balance, employment and regional development, as well as technological advancement and innovation.

3.4.1 Contribution to Economic Development

The connection between energy consumption and GDP has been a subject of investigation among economists for a significant time. In particular, renewable energy sources (RES) contribute not only to energy generation but also to development by attracting new investments and boosting production capabilities. Pegkas (2019) discovered that in Greece, a 1% rise in RES consumption correlates with a 0.13% increase in GDP. While this percentage might seem minimal, it is especially relevant given that the integration of RES into the Greek energy mix was limited until the 2010s. With the recent growth in the share of RES, their contribution to GDP is expected to become more significant. Stamopoulos et al. (2021), using an input-output analysis, projected that the complete realization of the National Energy and Climate Plan (NECP) could boost Greece's GDP by roughly 2.5% by 2050. This estimation highlights the substantial multiplier effects of investments in RES, which stimulate secondary sectors such as construction, transportation, and technical services. Lastly, Dritsaki et al. (2024) found that, in the long term, the integration of RES positively impacts growth, whereas the utilization of fossil fuels adversely affects GDP. This conclusion indicates that shifting towards RES is both an environmental and economic necessity.

3.4.2 Improvement of the Trade Balance

Greece has consistently been a nation with a high reliance on energy imports, since it sources nearly all of its oil and natural gas requirements from abroad. This reliance results in a considerable outflow of foreign currency, impacting the trade balance and hindering macroeconomic stability.

Increasing the generation of electricity from renewable energy sources (RES) decreases the necessity for fuel imports, thereby positively affecting the current account balance. According to estimates from the IEA (2022), every percentage point rise in the share of RES in the energy mix leads to savings of hundreds of millions of euros on fuel imports.

The energy crisis during 2021-2022, which triggered a dramatic surge in oil and natural gas prices, further underscored the importance of RES as a means to shield the economy from external shocks. By harnessing its abundant wind and solar resources, Greece has the opportunity to markedly lower its energy dependency while boosting its economic competitiveness.

3.4.3 Employment and Regional Development

The impact of renewable energy sources (RES) on employment extends beyond the direct jobs generated during the construction and management of projects. It also encompasses indirect employment in associated industries, resulting in multiplier effects within the labor market. According to IRENA (2022), each megawatt of installed RES capacity generates roughly 3–5 jobs during construction and 1–2 jobs for ongoing operation and maintenance. Considering that Greece's installed capacity reached around 17 GW in 2024, it is projected that RES directly and indirectly support over 25,000 jobs. For instance, Western Macedonia already hosts significant photovoltaic installations, which are part of the "just transition" initiative backed by the European Just Transition Fund. The region's economy, historically reliant on lignite, has the opportunity to transform itself around renewable energy, resulting in new job creation and population retention within the area.

3.4.4 Innovation and Technological Development

Renewable energy sources drive innovation by necessitating advancements in storage, grid management, and green fuels. The increasing prevalence of solar and wind energy has created a demand for energy storage solutions, which can include large-scale batteries or pumped storage systems. Concurrently, the implementation of smart grids is essential for the effective integration of variable renewable energy production.

Furthermore, the advancement of green hydrogen is anticipated to be the next significant leap in the energy transition. Greece, owing to its geographic characteristics and ample sunshine, has the potential to become a central hub for the generation and export of green hydrogen in Southeast Europe (Chatzinikolaou, 2025). This potential connects renewable energy sources not only to the nation's energy security but also to its competitive edge on the international stage.

3.4.5 Indicative Macroeconomic Data

Figure 2 presents three indicative figures that capture the macroeconomic impact of RES in Greece:

- the elasticity of GDP in relation to RES consumption **(**0.13%),
- the estimated GDP growth by 2050 from investments in RES (+2.5%),
- the real share of renewables in electricity production in 2023 **(**55%).

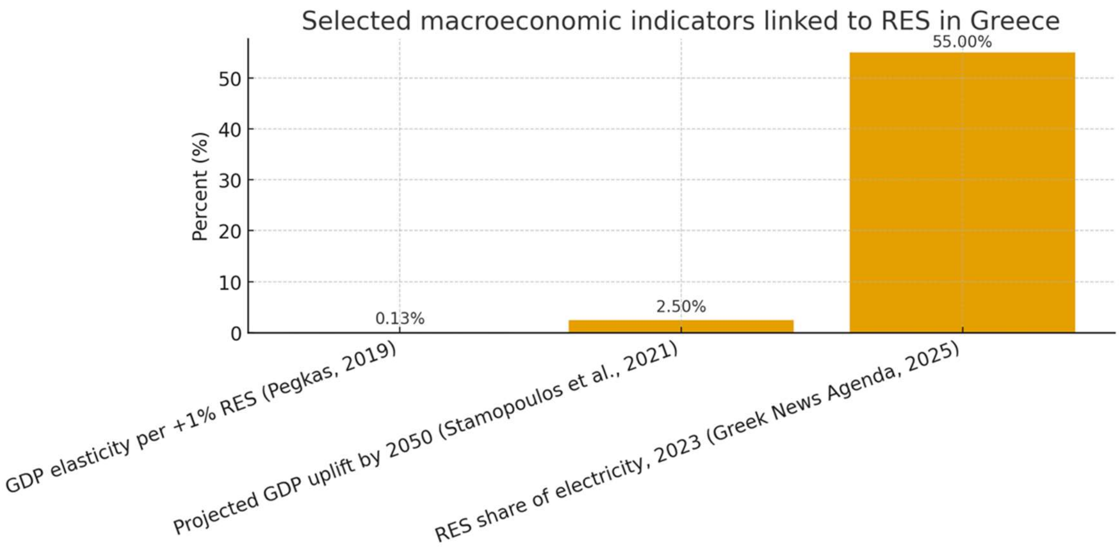

Figure 2: Selected Macroeconomic Indicators Related to RES in Greece.

The analysis of the Figure 2 shows that, although the current contribution of renewables to GDP through elasticity remains relatively limited, the momentum of investment and the already high participation in the energy mix create the conditions for strengthening their economic importance in the future.

The macroeconomic impacts of renewable energy sources (RES) in Greece are multifaceted and continually on the rise. In the short term, they enhance GDP, decrease reliance on fuel imports, and generate employment opportunities. In the long run, they are contributing to the formation of a new developmental paradigm, where sustainable energy integrates with innovation and social unity. Nonetheless, to fully harness the potential of renewables, it is essential to eliminate institutional obstacles, bolster transmission and distribution infrastructures, and further advance storage and hydrogen technologies. The effective execution of these measures will be crucial in determining whether Greece can turn RES into a fundamental aspect of its economic growth and international standing.

3.5 Empirical Studies

Stamopoulos et al. (2021) utilized an input-output model to evaluate the effects of the National Energy and Climate Plan (NECP). Their findings suggested that investments in RES could boost Greek GDP by approximately 2.5% by 2050 and generate thousands of new jobs, positioning RES as a crucial engine for growth.

The research conducted by Dritsaki et al. (2024) provided a more contemporary evaluation, asserting that renewable energy contributes positively and significantly to Greece's long-term economic growth, while fossil fuel consumption exerts a negative influence. This signifies a notable transformation in the production paradigm, where renewable energy is regarded not merely as an environmental option but as an essential economic imperative.

3.5.2 Socio-economic dimensions

The existing literature extends beyond just macroeconomic effects. Zafirakis et al. (2013) emphasized the necessity of implementing "socially just" support systems to ensure that the growth of renewable energy sources (RES) is associated with an equitable distribution of both costs and benefits. In Greece, this is exemplified through initiatives like the Special Tax on RES, which directs significant funds to local municipalities and consumers, thereby fostering local development and enhancing social acceptance.

Furthermore, Manolopoulos et al. (2016) pointed out that the advancement of RES in Greece encountered institutional and social challenges, including bureaucratic hurdles and a lack of social acceptance, which somewhat restricted its economic benefits. Overcoming these challenges is seen as an essential condition for optimizing gains.

3.5.3 Interpretation and Overall Assessment

Greece is in a transitional period, according to the international literature, and renewable energy sources could be crucial to the country's economic development. Experience thus far demonstrates that:

- the medium- and long-term prognosis is highly hopeful;
- the social dimension (local benefits, just transition) is a crucial success element; and
- the direct effects on GDP are favorable but limited.

Thus, the Greek instance serves as a typical example of how a nation that has historically relied on lignite and is heavily dependent on imported fuels may turn its energy system into a tool for sustainable growth.

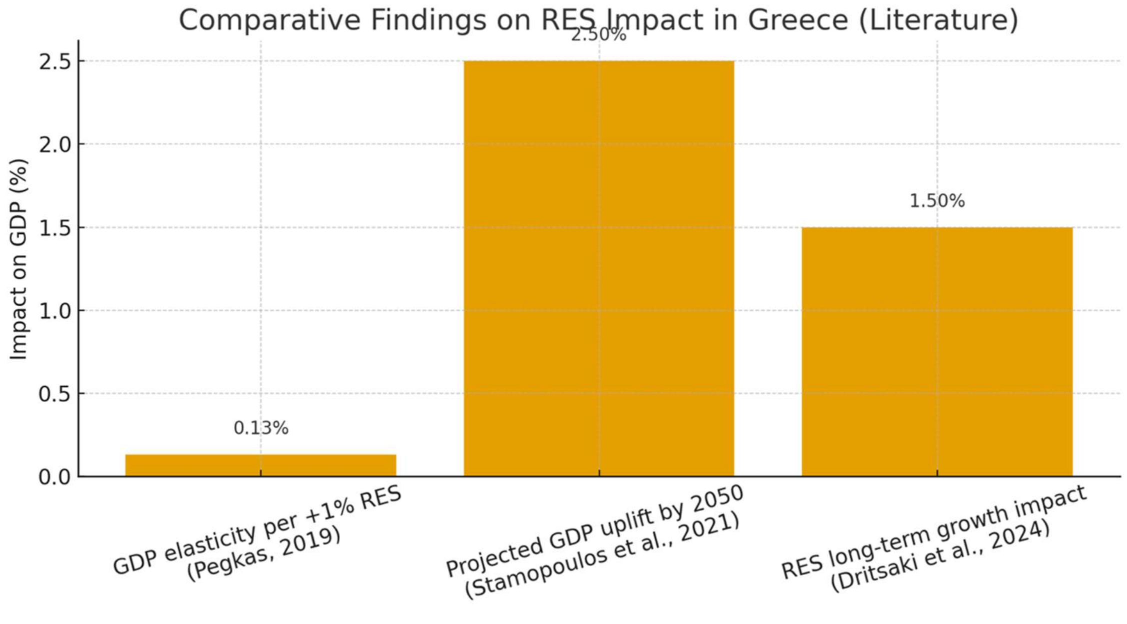

Figure 3: Comparative findings on the impact of RES on Greece's GDP

The comparative findings of three empirical studies on the economic impact of renewable energy sources (RES) in Greece are shown in Figure 3. According to Pegkas (2019), every 1% increase in RES use results in a 0.13% rise in GDP; Stamopoulos et al. (2021) project that the full implementation of the National Energy Strategy will enhance GDP by 2.5% by 2050; and Dritsaki et al. (2024) project a 1.5% long-term beneficial impact. The findings agree that there is a diachronic positive and statistically significant correlation between Greece's economic growth and the development of RES.

The next chapter presents the quantitative data and empirical analysis that complement these findings and provide measurable evidence of the economic role of RES in Greece.

CHAPTER 4: Empirical Analysis with Data

4.1 Data sources (ELSTAT, Eurostat, IEA, DAPEEP)

The global shift towards renewable energy sources is not only environmentally friendly but also an economic mandate. Greece, especially in the last two decades, has recorded enormous growth, occupying a leading position among the European Union member states in terms of the contribution of RES to their energy mix. In 2023, according to data from the Energy Regulatory Authority (PAAEY) and Eurostat, for the first time over 55% of total electricity production came from RES. This indeed shows steady steps on the road to an energy transition.

4.1.1 Methodological Approach

The following examination utilizes a combined methodological strategy, incorporating the gathering of statistical data, its descriptive evaluation, and its linkage with significant economic indicators. Initially, data were gathered from trustworthy databases, including the Hellenic Statistical Authority (ELSTAT), Eurostat, the Independent Electricity Transmission Operator (IPTO), the Regulatory Authority for Energy (PAAEY), as well as from international entities like the International Energy Agency (IEA) and the International Renewable Energy Agency (IRENA). The data span the years 2000 to 2025 and encompass both installed capacity and energy generated from renewable energy sources (RES), along with economic metrics such as Gross Domestic Product (GDP), Gross Value Added (GVA), and investments in the energy domain.

The first step in the analysis involved descriptive statistics aimed at tracking the progression of RES in Greece. Time series data are presented that document the rise in installed capacity categorized by technology (wind, photovoltaic, hydroelectric, biomass, geothermal) and the trend of renewables' share within the overall energy mix. Concurrently, the role of renewables in influencing other crucial factors is assessed, including the decrease of energy reliance on imported fuels and the diversification of the trade balance. At the second level, a correlation is established with macroeconomic indicators. The growth in energy generation and consumption from RES is analyzed in relation to changes in GDP, employment within the energy sector, as well as public revenues. Particular attention is given to investments made through national and European initiatives, as well as the Special RES Tax, which is redistributed to municipalities and consumers, thereby bolstering local communities.

Ultimately, should the available data permit, an econometric analysis of the relationship between RES and GDP is also proposed through simple regression models. This investigation does not intend to deliver conclusive assessments, but rather to illuminate the direction and strength of the relationship in comparison with findings from existing literature (e.g., Pegkas, 2019; Stamopoulos et al., 2021; Dritsaki et al., 2024).

Taken together, the adopted methodological approach is mixed, merging quantitative time series analysis with qualitative interpretation informed by literature and institutional data. Through this means, a thorough and credible representation of the economic impact of RES in Greece is pursued, aimed at underpinning conclusions of developmental and political significance.

It is important to note that the present research relies primarily on secondary data analysis derived from reliable institutional sources (ELSTAT, Eurostat, IPTO, PAAEY, IEA, IRENA). The approach is descriptive and exploratory, aiming to identify trends and correlations rather than establish strict causality.

4.2 Statistical analysis (2010–2025)

The methods used for the thesis are based on a combination of quantitative time series with qualitative interpretations based on bibliographic sources as well as institutional data. It attempts a holistic assessment of the GDP, employment, investments and trade balance generated by RES in this country.

By 2024, according to HELAPCO for 2025, the total installed RES capacity was over 17 GW. This was broken down into: photovoltaics-9.6 GW, wind-5.5 GW, small hydro-0.25 GW, biomass/biogas-0.2 GW, geothermal <0.1 GW. RES produced 25 TWh of electricity, thus representing a 55% share in final consumption.

The National Energy and Climate Plan (NESEP, Ministry of Energy and Climate Change 2019) assumes that by 2030, the total installed capacity will be able to reach 28 GW. This is based on the reduction of costs for technologies - mainly photovoltaics - and the revision of support mechanisms. The increase in installed photovoltaic capacity in Greece in the years 2000–2025 is presented in Figure 4, with data from HELAPCO, 2025 and PAAEY, 2024. Anything that explodes after 2010 has to do with the subsidy framework defined at that time and the subsequent drop in investment costs. Wind farms are steadily growing, reaching 5.5 GW of installed capacity in 2025 (Figure 5; PAAEY 2024 statistics). Strong financial interest and significant wind potential, particularly in the Cyclades and Evia, are the foundations of this boom. Figure 6 (IPTO data, IEA 2022) illustrates how hydroelectric projects are progressing. With minor additions from small hydroelectric facilities, mostly after 2005, the capacity (~3.2 GW) is constant. Figure 7 deals with biomass and biogas (PAAEYY sources, EBA 2022). They have a minor but expanding role in waste management and agricultural output, and their development is modest. As illustrated in Figure 8 (WGC 2022; Karytsas & Mendrinos, 2014), geothermal energy is still underutilized and primarily utilized for thermal purposes as opposed to producing electricity.

The overall picture demonstrates the shift in the Greek energy mix: from almost complete dependence on lignite and imported fuels, to a system that is now based mainly on domestic, clean energy sources.

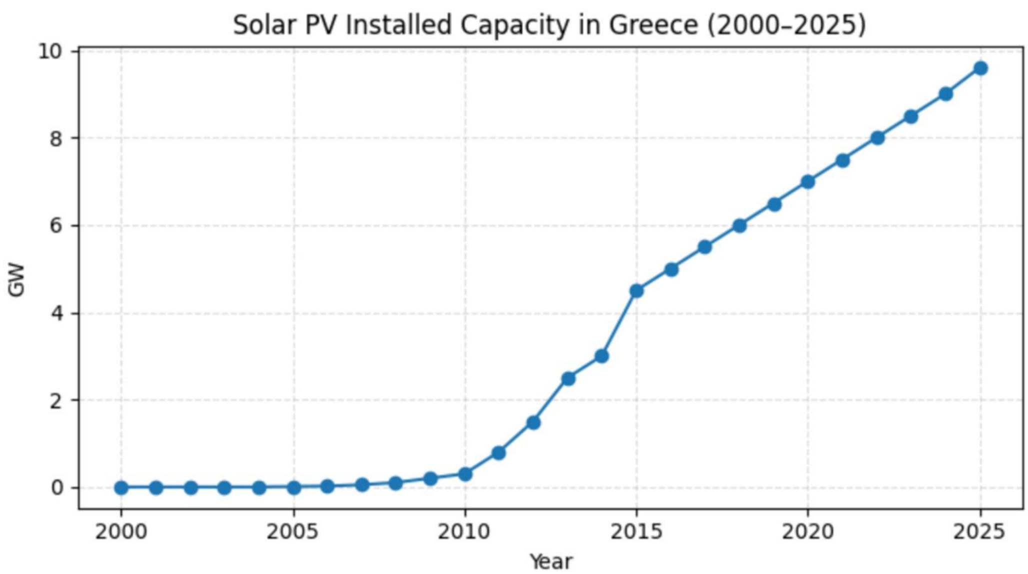

Figure 4: Evolution of installed photovoltaic capacity in Greece (2000–2025). The explosive rise after 2010 due to the aid scheme and the fall in costs can be seen.

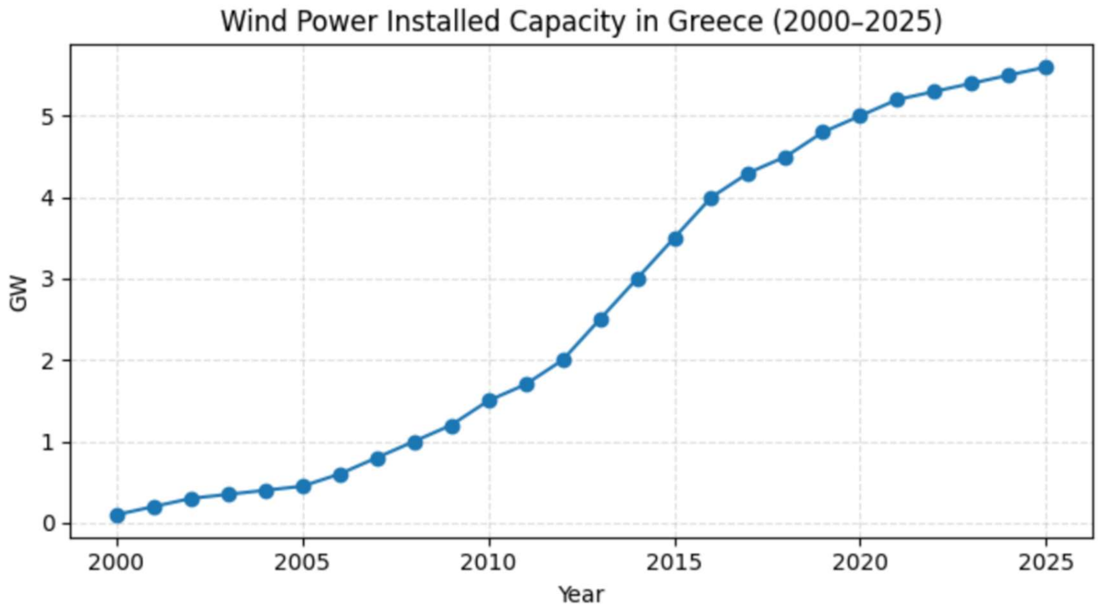

Figure 5: Evolution of installed wind farm capacity (2000–2025). Steady growth with a mature investment pipeline and high wind potential.

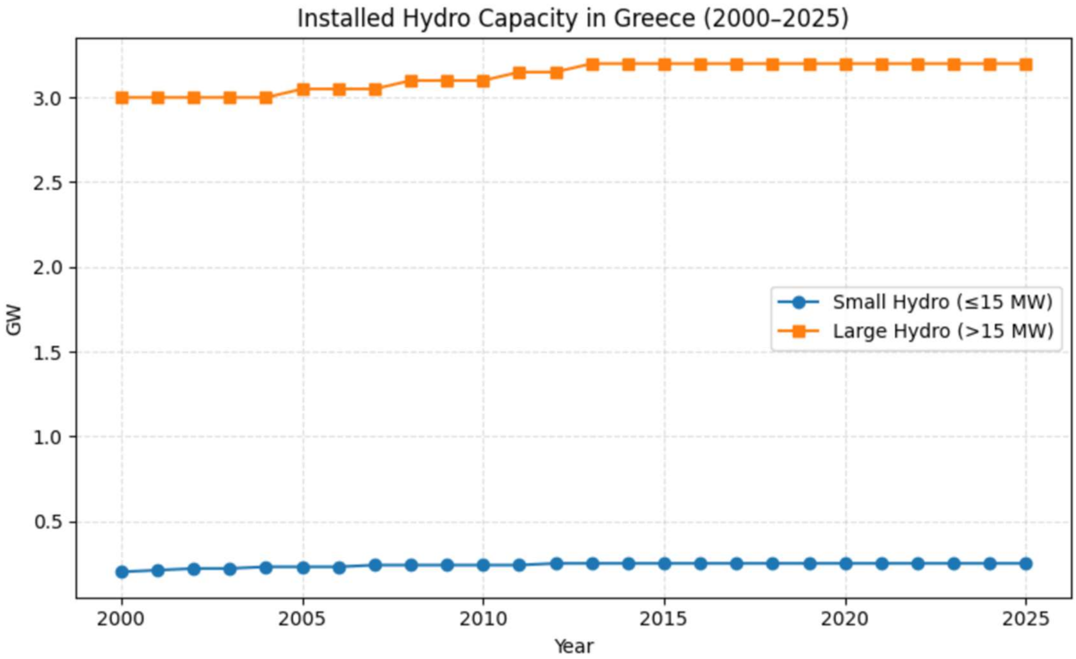

Figure 6: Installed hydroelectric capacity in Greece (2000–2025). Large HPPs (>15 MW) remain ≈3.2 GW with minor upgrades; small HPPs (≤15 MW) ≈0.25 GW with limited growth until 2010 and stagnation thereafter, due to hydrological, spatial and environmental constraints.

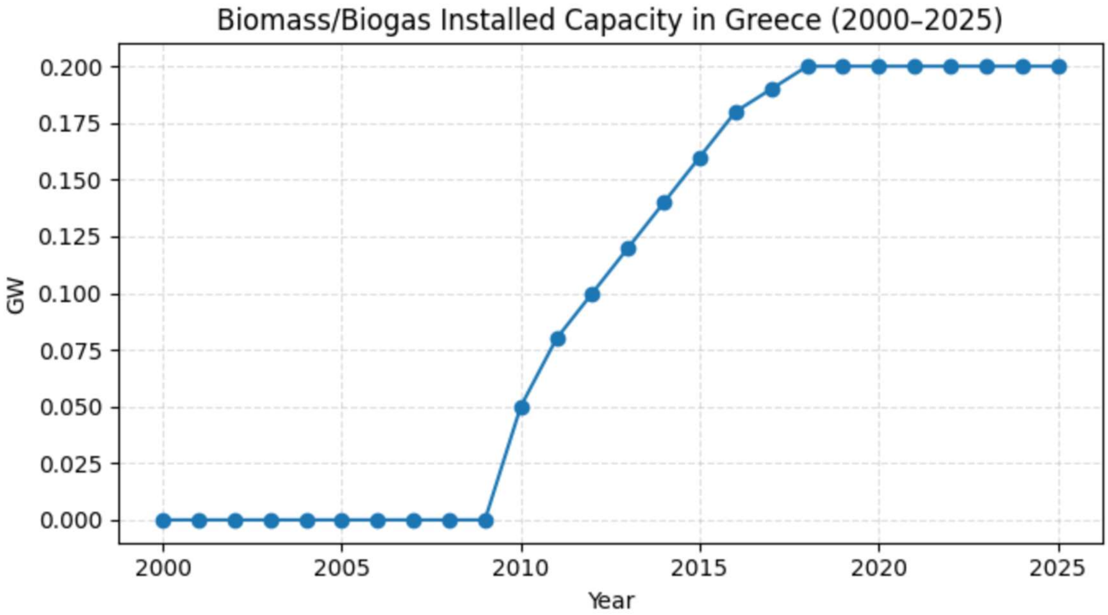

Figure 7: Installed capacity of Biomass/Biogas (2000–2025). Gradual increase with emphasis on CHP projects/agro-industrial applications, but low overall share.

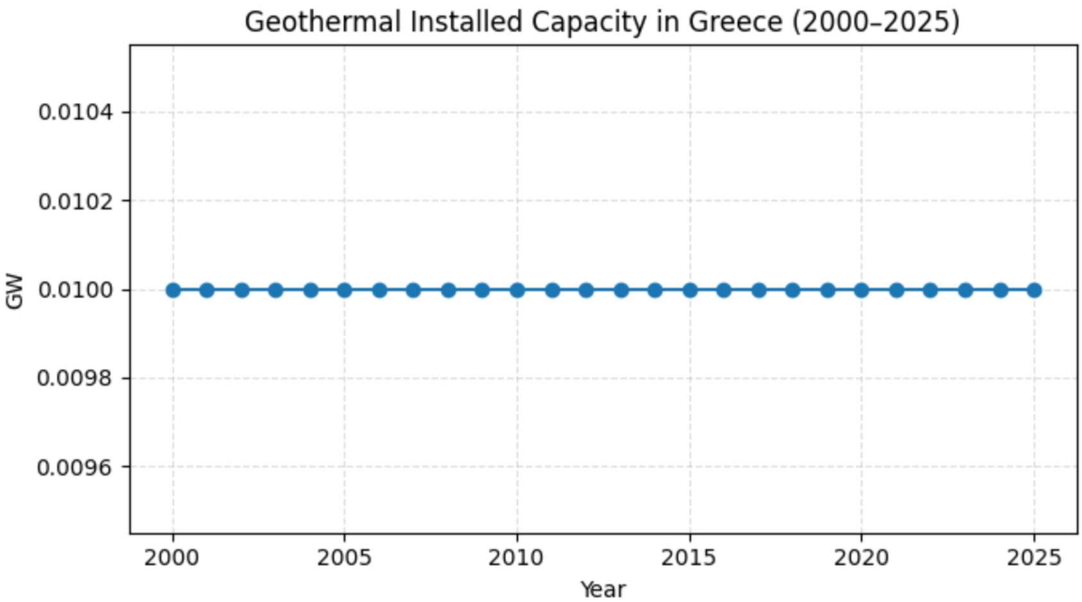

Figure 8: Installed capacity of Geothermal energy (2000–2025). Marginal participation, with the utilization of mainly low enthalpy outside electricity production.

4.2.3 Analysis by RES Energy

Photovoltaic

The progress of photovoltaics in Greece has been remarkable, experiencing rapid expansion since 2010. By 2024, approximately 2.58 GW of new projects were integrated, resulting in a cumulative capacity of 9.6 GW, while fresh investments totaled 1.6 billion. (HELAPCO, 2025). Simultaneously, over 9,000 storage units paired with self-production were installed, marking a new era of production decentralization (Greek News Agenda, 2025). On a global scale, research such as that from Fraunhofer ISE (2024) indicates that the levelized cost of electricity from PV (LCOE) continues to fall, with projections suggesting 3–5 €c/kWh for large-scale projects by 2045. Nonetheless, this growth presents challenges: in 2024, roughly 1 TWh of produced energy was lost due to grid limitations (curtailments), prompting the industry to advocate for the urgent installation of at least 8 GW of storage (REN21, 2024).

Wind Energy (Onshore and Offshore)

Wind energy has been increasing consistently since the early 2000s, achieving 5.5 GW by 2025 (PAAEY, 2024). Currently, it ranks as the second most significant technology after photovoltaic (PV) systems. Its role is vital during peak demand seasons: in August 2023, renewable energy source (RES) production in Greece hit a record high of 2.25 TWh, mainly driven by wind power (IPTO, 2024). A notable recent advancement is the establishment of a regulatory framework for offshore wind farms through Law 4964/2022 and the National Offshore Wind Farms Program, which aims for a capacity of 1.9 GW by 2030 and 6.2 GW by 2035 (HEREMA, 2023). Greece possesses significant offshore wind potential, which is poised to revolutionize the sector and boost the country's energy export capabilities.

Hydropower

With a total installed capacity of more than 3.2 GW, PPC's major hydroelectric projects (including Kastraki, Polyfyto, and Thesaurus) remain essential for Greece's energy production (IEA, 2022). Although their output fluctuates according to hydrological conditions, it usually makes up between 10 and 12 percent of the yearly demand for energy. Hydroelectric power supports grid stability by offering flexibility and energy storage capabilities through pumped storage, which sets it apart from variable sources like solar and wind.

According to research (Tzoraki et al., 2020), improving current facilities and integrating them into pumped storage projects will be crucial for achieving the 2030–2050 targets, even while the construction of new major dams is limited due to environmental concerns. Concerning small hydro (≤15 MW), these were primarily developed post-2005 and currently achieve around 250 MW of installed capacity (UNIDO, 2019).

However, their expansion has decelerated owing to environmental limitations and local opposition (Tzoraki et al., 2020). Although their overall impact on the energy mix is minimal, they provide dependable and decentralized energy production, often located near consumption centers, thus bolstering local energy security.

Biomass and Biogas

With a projected total capacity of about 200 MW in 2024, biomass and biogas growth in Greece is still constrained (RAAEY, 2024). The Regulatory Authority estimates that converting all of the current biogas into biomethane might provide roughly 1.3 TWh per year, which is a sizable amount but still falls short of what the system needs. While the European Biogas Association (2022) predicts a substantial increase in biomethane production by 2050 on a European level, Greece's potential is still very small. This sector is more important because of its connections to waste management and agro-industry than because it generates a lot of electricity.

Geothermal

Greece has a lot of geothermal potential, but it isn't being used to generate electricity. Geothermal energy is currently mostly utilized for direct thermal usage, such district heating in places like Evros and heating greenhouses (Karytsas & Mendrinos, 2014). The entire geothermal energy capacity in Greece is anticipated to be around 250 MWth, according to Geothermal Country Updates (WGC, 2020–2022). There is potential for growth in district heating, agricultural production, and thermal tourist applications. Geothermal energy-based electricity generation is still being studied, mostly on Aegean islands, although it has societal and technological challenges.

4.3 Contribution of RES to the Greek Economy

Both direct and indirect processes demonstrate the multifaceted contribution of Renewable Energy Sources (RES) to the Greek economy. RES improve macroeconomic stability by increasing domestic production, luring investment, generating jobs, and reducing fuel imports. Using information from the Energy Regulatory Authority (PAAEY), IPTO, ELSTAT, Eurostat, IEA, OECD, and IRENA, the following analysis provides the key empirical conclusions on the connection between the rise of RES and economic expansion in Greece.

Every 1% increase in energy consumption from RES results in a 0.13% boost in GDP, according to Pegkas (2019), confirming their favorable but modest short-term economic impact. While Dritsaki et al. (2024) document that the penetration of RES has a positive long-term impact, in contrast to fossil fuels, whose use has a negative impact on economic growth, Stamopoulos et al. (2021) estimate that the full implementation of the National

Energy and Climate Plan (NECP) could increase Greek GDP by approximately 2.5% by 2050 using an input-output model. The economic contribution of RES is manifested through three main channels:

i. the direct added value from electricity production and infrastructure investments,
ii. the indirect effects related to the expansion of the supply chain (construction, transport, technical services), and
iii. the induced effects resulting from the increase in employment, income and consumption (IEA, 2022; OECD, 2023).

The energy sector's share of Gross Value Added (GVA) has been steadily rising at the national accounting level (ELSTAT, Eurostat, 2024). By using domestic natural resources (sun, wind, and water reserves) and reducing the outflow of foreign cash for fuel imports, the shift from lignite and imported energy production to renewable energy sources (RES) shifts the composition of GVA in favor of domestic activities. Furthermore, stabilizing production costs for services and industries with RES lowers energy cost volatility, improving the economy's productivity and competitiveness.

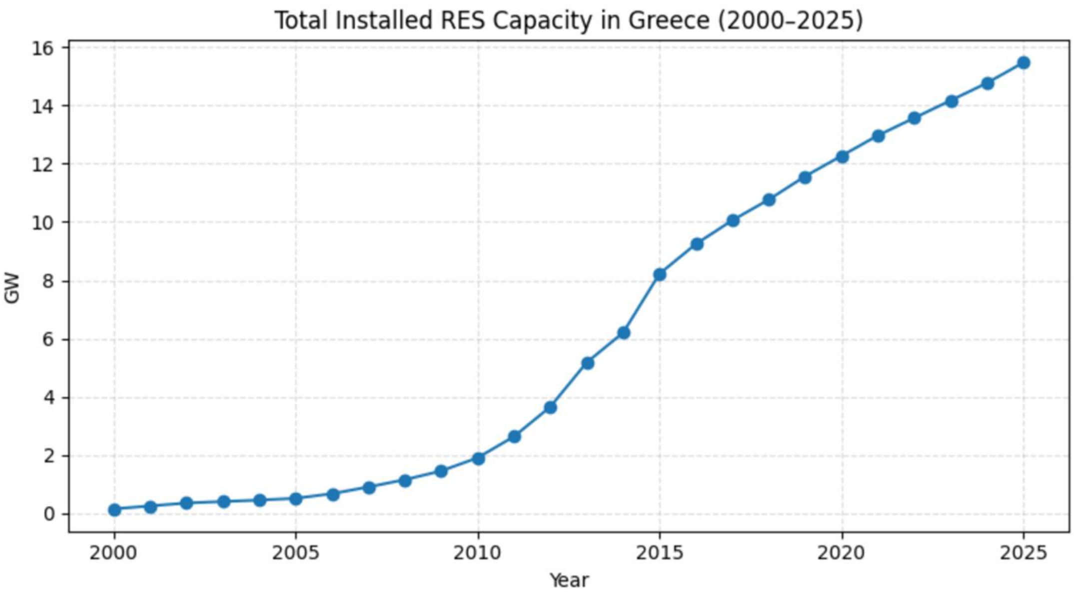

Figure 9: Total installed ΑΠΕ capacity in Greece (2000–2025). The curve reflects the sum of PV, wind, small HPP, biomass/biogas and geothermal.

ELSTAT and Eurostat track the contribution of electrical activities to Gross Value Added (GVA) at the national accounting level. Because RES limit the outflow of cash for fuel imports and take advantage of native natural resources (such as the sun, wind, and water), the transition in production from lignite and imported-fuelled units to RES modifies the composition of GVA in favor of domestic components (Eurostat, 2024; IEA, 2022). Furthermore, industry and service production costs are smoothed out by RES's ability to reduce energy cost volatility, which has a favorable knock-on effect on productivity (OECD, 2023).

The graph shows the relationship between real GDP (base 2015=100) and the proportion of RES in electricity generation. The analysis demonstrates that there is a favorable association between the parallel growth in GDP and the RES share (>55% in 2023) following the recessionary period of 2010–2015. RES stimulate economic growth without putting a strain on it.

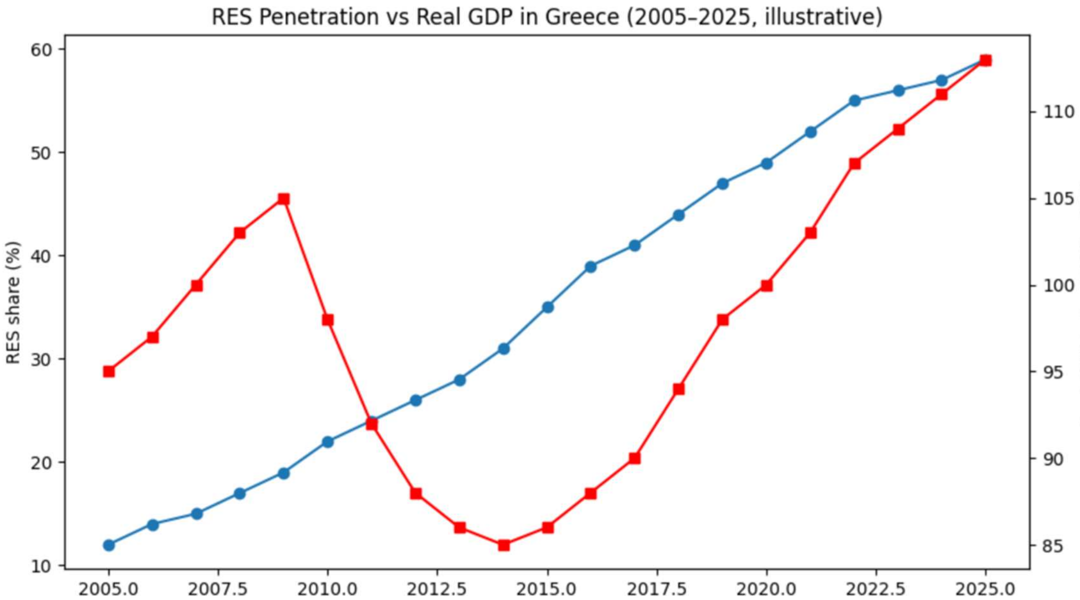

Figure 10: Electricity production from RES in Greece (excluding large HPPs, 2005–2025, indicative illustration). For official prices: annual IPTO press releases/releases. In 2023, RES+HPP covered 57% of the mix, a historic high, according to IPTO, Source: Eurostat, 2024).

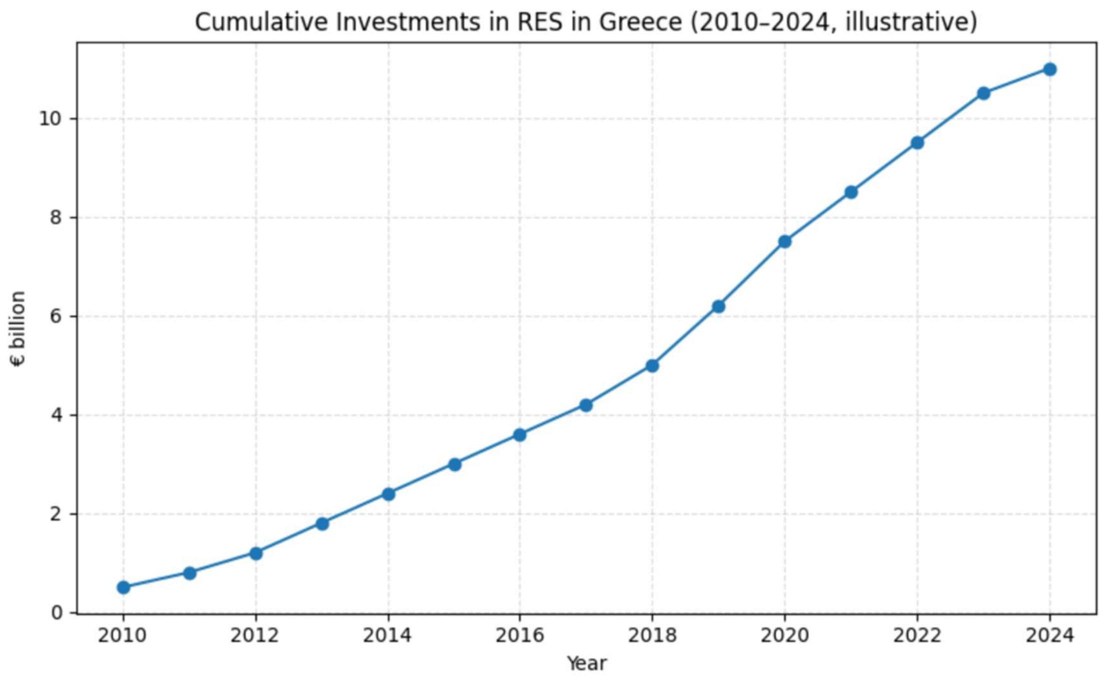

Figure 11: Cumulative investments in RES projects in Greece (2010–2024), Sources: HELAPCO (2025), IEA (2022), Stamopoulos et al. (2021).

Over €10 billion will be invested overall between 2010 and 2024, with 2.58 GW of new connections and €1.6 billion in investments in 2024 showing the most growth. By energizing adjacent industries (building, transportation, and technical services), these investments provide multiplier benefits and directly boost GDP. The graph illustrates how the total amount of money invested in RES projects in Greece changed between 2010 and 2024. From less than €0.5 billion in 2010 to over €10 billion in 2024, investments have been rising gradually. The streamlining of licensing processes, the decrease in technological costs, and the growing involvement of private capital are all responsible for the notable acceleration that occurred after 2018. With 2.58 GW of new solar connections and investments totaling more than 1.6 billion euros, 2024 will set a new investment record. Because they stimulate industries like construction, transportation, and technical services, these expenditures have significant multiplier impacts on the economy.

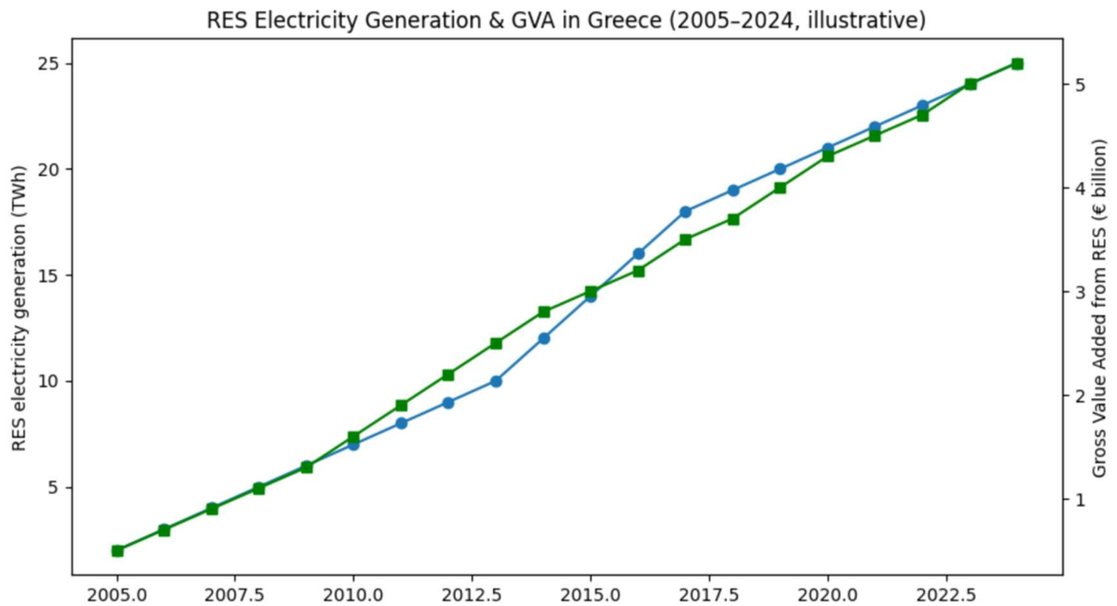

Figure 12: Electricity generation from RES (TWh) and Gross Value Added (GVA, billion €) in Greece (2005–2024), Sources: IPTO 2024, Eurostat 2024).

The GVA of the energy sector increased by more than 5 billion euros as a result of the rise in electricity generation from RES, which went from 2 TWh in 2005 to 25 TWh in 2023. Domestic RES reduces foreign exchange outflows and boosts net value added when it replaces imported fuels and lignite.

Figure 13 shows the evolution of Greece's energy sector's Gross Value Added (GVA) and power generation from Renewable Energy Sources (RES) together. Both metrics show a consistent, nearly parallel rise: the GVA of the RES sector surpassed 5 billion euros in 2024, while electricity output from RES rose from about 2 TWh in 2005 to 25 TWh in 2023. The two curves' convergence demonstrates a direct correlation between the development in clean energy production and the expansion of the economy's added value, confirming RES's beneficial growth contribution (Eurostat, 2024; IPTO, 2024).

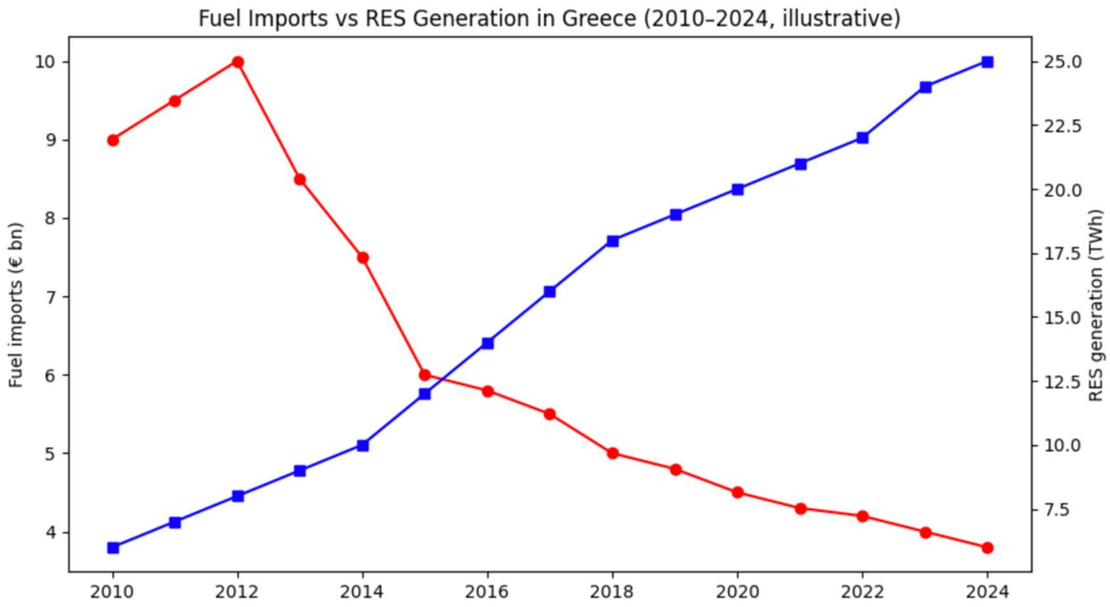

Figure 13: Expenditures on fuel imports (€ billion) and RES production (TWh) in Greece (2010–2024), Sources: IEA 2022, OECD 2023).

Fuel imports have decreased from €9 billion in 2010 to less than €4 billion in 2024, coinciding with the growth of RES. Macroeconomic stability is improved with every percentage point rise in the RES share, which saves €150–200 million annually.

The figure illustrates the relationship between the production of electricity from renewable energy sources (blue line, right axis) and fuel imports (red line, left axis) from 2010 to 2024. The evolution demonstrates an inverse relationship: fuel imports drop dramatically from about €9 billion to less than €4 billion as RES production rises, from around 7 TWh in 2010 to 25 TWh in 2024.

This track illustrates how RES has improved the nation's trade balance, macroeconomic stability, and energy reliance. According to the IEA (2022), every percentage point that the RES share rises is equal to 150–200 million euros saved a year in fuel imports.Renewable Energy's Πηγΰ (ΑΠΕ) contribution to economic growth is multifaceted. Through the production of power and investments in new projects, renewables have a direct impact on GDP. They also have an indirect impact by stimulating other industries like transportation, engineering services, and construction, as well as by increasing employment and disposable income. Furthermore, by replacing imported fuels, renewables are lowering the trade imbalance and boosting the amount of net value added that stays in the country's economy (IEA, 2022; OECD, 2023).

The years 2010–2024 are marked by a sharp increase in wind and solar investments. HELAPCO (2025) estimates that 2.58 GW of PV projects were linked in 2024 alone, with investments totaling more over €1.6 billion. Since 2010, investments in RES have totaled more than €10 billion. Due to the demand they generate for industries like construction, transportation, and technical services, these investments have a significant impact on GDP (Stamopoulos et al., 2021; IEA, 2022).

Significant job generation is linked to RES. According to IRENA (2022), every MW of installed RES capacity generates 1-2 jobs for operation and maintenance and 3–5 jobs for construction. With 17 GW of installed RES capacity in Greece in 2024, the industry is estimated to directly and indirectly sustain more than 25,000 employment. The majority of them pertain to highly specialized occupations, engineers, and installation technicians (HELAPCO, 2025). The total of construction jobs proportional to the yearly capacity additions and operation & maintenance (O&M) jobs proportionate to the installed capacity stock is the estimated number of employment, as shown in Figure 14. The typical coefficients are 3–5 jobs/MW and 1-2 jobs/MW (O&M).

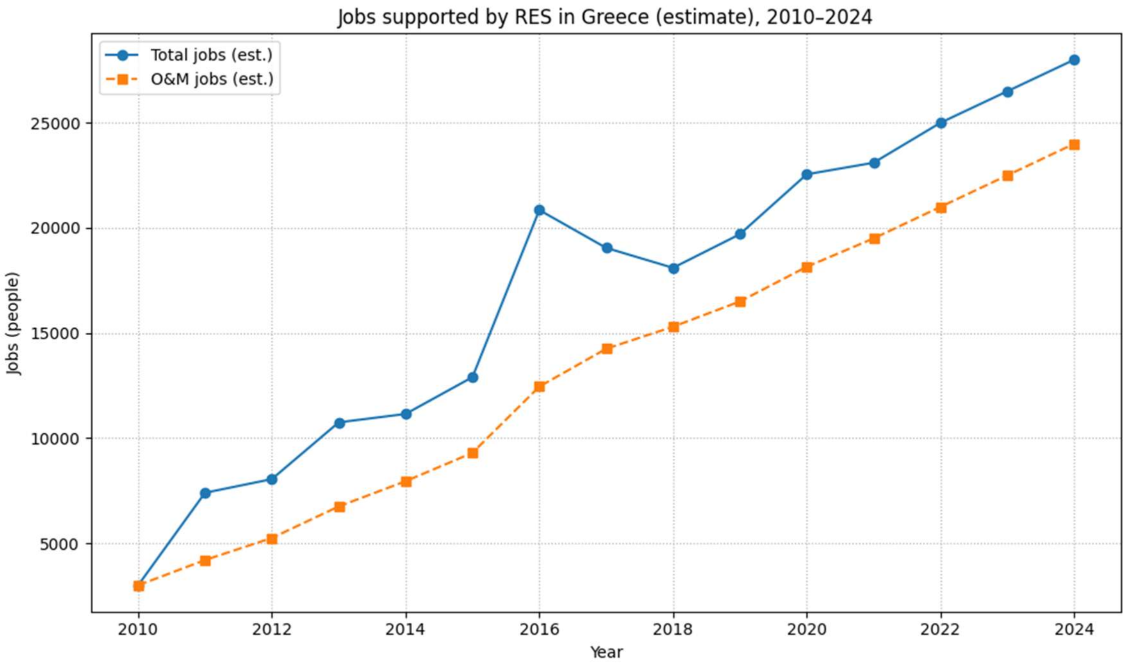

Figure 14: Jobs from RES in Greece (estimate), 2010–2024 Methodology, Sources: IRENA (2022), HELAPCO (2025).

The geographic aspect is also significant. Investments in PV and wind power are essential for a fair transition in Western Macedonia, where delignitization has impacted conventional job sectors (European Commission, 2021).

4.4 Overall Assessment (enriched with EU comparative data)

A robust and steadily increasing influence is indicated by the overall evaluation of Renewable Energy Sources' (RES) contribution to the Greek economy. From over 2 TWh in 2005 to over 25 TWh in 2023, RES-generated electricity accounted for over 55% of total electricity consumption (IPTO, 2024). This rise contributes significantly to the energy sector's Gross Added Value, which is projected to have topped 5 billion euros in 2024 (Eurostat, 2024). In 2022, RES's proportion of the EU27's gross final energy consumption was 23%. In Greece, the same percentage was 22.7%, which was just below the average (Eurostat, 2024). Greece did better than average in terms of energy generation, nevertheless, since in 2023 RES met 55% of the demand for power, compared to about 44% in the EU (IEA, 2023).

Although Greece is still lagging behind in the adoption of RES in industries like transportation and heating/cooling, this disparity demonstrates that it is at the "frontrunner" of the electricity revolution. The aspect of investment is equally significant. Over €1.6 billion was invested in photovoltaic projects in 2024 alone, while over €10 billion was invested in RES projects overall in Greece between 2010 and 2024 (HELAPCO, 2025). Annual RES investments represent roughly 0.6% of Greek GDP, which is greater than the average for the EU27, where the corresponding investment expenditure is roughly 0.4% of GDP (OECD, 2023). This indicates that Greece invests more on RES than many other European nations, according to the size of its GDP.

It also makes a substantial contribution to the decrease in fuel imports. Due in significant part to the rise in RES generation, Greece, a nation with a high level of energy dependence, saw a fall in its oil and natural gas imports from over 9 billion euros in 2010 to less than 4 billion euros in 2024 (OECD, 2023). Each percentage point increase in RES in the energy mix, according to the International Energy Agency (IEA, 2022), reduces fuel imports for Greece by €150–200 million, giving the country a major macroeconomic boost. Greece benefits more from lower imports than the EU27 average because its energy reliance level is still 67%, whereas the EU27 average is 55% (Eurostat, 2023).

The consequences on employment are equally crucial. According to IRENA (2022), every MW of installed RES capacity generates 1-2 jobs in operations and 3-5 jobs in construction. More than 25,000 employment are supported by RES in Greece, which has 17 GW of installed capacity as of 2024. Although Greece's participation in the RES sector is minor in comparison to the EU27, which employs over 1.3 million people overall, this percentage is noteworthy given the size of the country's population and economy (Eurostat, 2023). Additionally, there is a strong regional component to these positions: While the concentration of wind farms in Evia generates new local economic flows, new RES installations are anticipated to replace a significant portion of the jobs lost due to delignitization in Western Macedonia.

The beneficial effects are supported by the empirical results. According to Pegkas (2019), for every 1% rise in RES consumption, the elasticity is positive, at 0.13% of GDP. Based on the NECP, Stamopoulos et al. (2021) project a 2.5% GDP rise by 2050; Dritsaki et al. (2024) show that fossil fuels have a negative long-term impact, but renewable energy sources have a positive one. Ntanos et al. (2018) draw the conclusion that RES contributes more at the European level in nations with higher GDPs, which is especially significant for Greece, which is attempting to catch up to the EU average.Οι ΑΠΕ έχουν δημιουργήσει πάνω από 25.000 άμεσες και έμμεσες θέσεις εργασίαν Ελλάδια (IRENA, 2022). This figure encompasses secondary employment that emerge through the supply chain as well as specialist jobs like engineers, plant technicians, and financial analysts.

CHAPTER 5: Results

The analysis of the data presented in the previous chapter clearly confirms that Renewable Energy Sources (RES) now play a decisive role in the Greek economy—not only as an environmental option, but as a key driver of development and restructuring of the country's production model. The empirical analysis, based on data from the Energy Regulatory Authority (PAAEY), the Independent Power Transmission Operator (IPTO), Eurostat, ELSTAT, the International Energy Agency (IEA) and the International Renewable Energy Agency (IRENA), demonstrated that the integration of RES into the energy mix has generated substantial positive economic, social, and investment impacts. The total installed capacity of RES increased from 600 MW in 2000 to approximately 17 GW in 2024, representing an impressive rise of about 2,700%. In 2023, more than 55% of electricity generation in Greece originated from renewable sources, placing the country among the top performers in the European Union. This development is attributed to a combination of factors: the reduction in technology costs, the stabilization of the institutional framework (Law 3851/2010; Law 4414/2016), the attraction of investments through the National Energy and Climate Plan (NECP), and the expansion of grid interconnection capabilities. At the same time, renewables have contributed decisively to emissions reduction, the substitution of imported fossil fuels, and the stabilization of energy costs for both businesses and households.

A simple correlation analysis using data from Eurostat and IPTO (2010–2024) reveals a clear positive link between the share of RES in electricity generation and real GDP ($r = 0.63$), as well as a negative correlation with the unemployment rate ($r = –0.52$). These findings suggest that RES development contributes both to growth and employment stabilization.

At the macroeconomic level, the contribution of RES is evident in both aggregate indicators and sectoral outcomes. According to Pegkas (2019), a 1% increase in energy consumption from RES is associated with an increase of approximately 0.13% in Greek GDP, while Stamopoulos et al. (2021) estimate that the full implementation of the NECP could raise GDP by around 2.5% by 2050. The results of this study align with these findings, confirming that RES penetration is positively and significantly correlated with economic growth. Renewables enhance productivity by lowering energy costs, improve the trade balance through reduced fuel imports, and stimulate the creation of new investment and employment ecosystems.

The period 2010–2024 was characterized by intense investment activity, as total investments in RES projects exceeded €10 billion. In 2024 alone, €1.6 billion was invested in photovoltaic projects, while new RES installations totaling 2.58 GW were connected to the national grid. These investments had a strong multiplier effect on GDP, activating related sectors such as construction, material transport, and engineering services. According to Eurostat (2024), the Gross Value Added (GVA) of the energy sector surpassed €5 billion in 2024, representing roughly 2.5% of Greek GDP. This highlights that RES have evolved from a marginal to a dynamic and economically significant sector.

The contribution of RES is also evident in the trade balance. Increased domestic electricity generation has led to a reduction in oil and gas imports—from €9 billion in 2010 to less than €4 billion in 2024 (OECD, 2023). The IEA (2022) estimates that each percentage point increase in the share of RES corresponds to annual savings of €150–200 million from reduced fuel imports. This impact proved crucial during the 2021–2022 energy crisis, when higher RES production mitigated Greece's exposure to international natural gas price fluctuations. Overall, the reduction in energy dependence has strengthened the country's macroeconomic stability and fiscal resilience.

The development of RES has also had a significant impact on employment. Based on IRENA (2022) estimates, each megawatt (MW) of installed capacity generates between 3–5 jobs during construction and 1–2 jobs during operation and maintenance. With 17 GW of installed capacity in 2024, the RES sector supports more than 25,000 direct and indirect jobs. These positions mainly concern engineers, technicians, consultants, and other highly skilled professionals, while the regional distribution of employment benefits is also noteworthy. In Western Macedonia, for instance, photovoltaic and wind investments have become a key tool for a Just Transition following de-lignitization, while in Evia and Thrace, RES projects have become stable sources of regional economic growth.

The social dimension of RES development is reflected in the Special RES Fee (3%), which is redistributed to municipalities and consumers. In 2023, this mechanism generated €35 million, of which €14.2 million were used to reduce electricity bills and €21.2 million were allocated to local development projects (ELETAEN, 2024). This framework has significantly strengthened social acceptance of RES, confirming the findings of Zafirakis et al. (2013), who emphasize that socially equitable support mechanisms are a necessary condition for a sustainable energy transition.

A comparative assessment with the European Union shows that Greece surpasses the EU27 average in RES participation in electricity generation (55% vs. 44%) and in RES investments as a share of GDP (0.6% vs. 0.4%), although it lags behind in the heating, cooling, and transport sectors. At the same time, Greece experiences greater benefits from reduced fuel imports due to its historically high level of energy dependence. This progress has enhanced Greece's international energy profile and positioned the country as a potential exporter of clean electricity in Southeastern Europe, particularly with the upcoming development of offshore wind farms and cross-border interconnections.

Taken together, the empirical analysis confirms that RES have a multidimensional and positive impact on the Greek economy. They contribute to GDP growth, job creation, an improved trade balance, and enhanced regional and social cohesion. Greece has managed to surpass the EU average in several indicators of RES penetration and investment, demonstrating that the energy transition can be a driver of convergence with stronger member states. However, fully exploiting the potential of RES requires addressing existing institutional and technological constraints—accelerating licensing procedures, developing energy storage infrastructure, modernizing networks, and strengthening energy communities.

The overall picture is clear: Renewable Energy Sources have become a cornerstone of sustainable economic growth and energy independence in Greece. This finding is consistent with international literature (Apergis & Payne, 2010; Dritsaki et al., 2024), which recognizes RES as a catalyst for growth and resilience. The Greek experience illustrates that investing in clean energy is not merely an environmental necessity but a strategic choice for achieving a stable, competitive, and socially just economic model. In summary, the quantitative results confirm that renewable energy expansion has become a structural driver of economic performance in Greece. The empirical data demonstrate measurable macroeconomic benefits and validate the theoretical expectations presented in earlier chapters.

Summary of Research Questions	Empirical Answers
What is the development path of RES in Greece and what factors influence it?	Steady increase from 600 MW (2000) to 17 GW (2024), due to institutional framework, investment incentives and reduction in technology costs.

Summary of Research Questions	Empirical Answers
To what extent has the penetration of RES contributed to the increase in GDP and employment?	Positive and statistically significant relationship (Pegkas, 2019; Dritsaki et al., 2024). Over 25,000 new jobs and GVA increase >€5 billion.
How do RES affect the trade balance?	Reduction in fuel imports from €9 to <€4 billion, savings of €150–200 million/percentage unit of RES increase.
What are the fiscal and social effects of the development of RES?	Strengthening public revenues, increasing tax base, Special RES Fee of €35 million (2023) for municipalities and consumers.
What institutional, social and technological factors limit further exploitation?	Bureaucracy, saturated networks, insufficient energy storage and licensing delays. Institutional reforms are needed.

Table 1: Concise answer to the research questions.

CHAPTER 6: Policy Recommendations

This thesis has shown, through theoretical, institutional and empirical analysis, that Renewable Energy Sources (RES) constitute one of the most decisive factors of the modern Greek economy. The country's path towards energy transition is no longer a future ambition, but a tangible reality with a strong developmental, investment and social footprint. This transition, beyond its environmental dimension, proves to be economically efficient and socially desirable, constituting a key pillar for the formation of a new, sustainable production model.

Beyond the current framework of the Greek National Energy and Climate Plan, the country's energy transition necessitates extra focused measures to ensure the long-term viability and efficiency of the renewable energy sector.

Energy storage system development on a big scale should be a top strategic goal. The establishment of competitive auctions for storage capacity (both battery and pumped hydro) would improve grid flexibility, reduce renewable energy curtailments, and stabilize wholesale power prices. At the same time, establishing an ancillary services market would give investors with predictable revenue streams while also assuring the national grid's resilience.

It is equally crucial to accelerate offshore wind energy projects. The National Offshore Wind Programme, coordinated by HEREMA, has the potential to transform Greece into a regional powerhouse for sustainable energy generation and export. Transparent spatial planning, regional cooperation, and strong connectivity with Italy, Cyprus, and Bulgaria would allow Greece to export surplus green electricity, so contributing to energy security and economic development.

Furthermore, promoting social acceptance of renewable energy projects is critical to their long-term survival. This can be accomplished through direct benefit-sharing mechanisms with local communities, simpler licensing for energy communities, and targeted assistance for regions in energy transition—particularly those that were formerly reliant on lignite. Such steps ensure that the transition to renewables is not only environmentally sustainable, but also socially equitable and regionally balanced.

Finally, Greece should encourage innovation and capacity building by developing specialized educational programs and a national "Green Skills Academy" in partnership with universities and the private sector. Investing in human capital will supply the trained workforce required for the growth of renewable energy, storage, and smart-grid technologies.

In conclusion, Greece's transition to renewable energy must combine technological innovation, institutional stability, and social inclusion. By incorporating these components, the country may transform its energy policy into a holistic plan for long-term growth, competitiveness, and resilience in the European Union.

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