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Challenges and Opportunities in the Renewable Energy Transition in Europe

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Abstract. The transition to renewable energy is pivotal for the European Union (EU) in its efforts to combat climate change and reduce reliance on fossil fuels. This article examines the challenges and opportunities associated with the EU's target of achieving at least 42.5% renewable energy consumption by 2030. Utilizing a comparative analysis of EU member states, it is assessed the renewable energy shares, achievements, and gaps. The methodology employed in this research is a mixed-method approach combining quantitative and qualitative analyses to evaluate the progress of renewable energy adoption in the EU and the barriers to achieving the 2030 targets. The analysis highlights the role of targeted policy interventions and increased investment in accelerating renewable energy deployment. Ultimately, this study underscores the need for cohesive strategies to enhance the resilience and sustainability of the EU's energy system as it strives to meet its climate objectives.
Keywords: *renewable energy, European Union, energy transition, climate change, sustainability, energy policy*

Introduction

The expansion of the renewable energy sector has reached an unprecedented scale, posing a critical challenge to the existing energy infrastructure. The rapid growth in electricity generation has placed considerable pressure on Member States' national energy systems, despite significant investments in grid modernization and expansion of transmission capacity. Despite these efforts, energy grids are not always equipped to handle the rapidly accelerating pace of renewable generation. In order to overcome these challenges, the EU must direct its attention towards the development of local energy communities. The direct involvement of local communities facilitates the energy transition and also ensures a higher level of acceptance and support from local residents. This participatory approach reduces the potential for conflict and resistances that can arise when energy infrastructure is perceived as centrally imposed without taking into account the needs and wishes of local communities. Therefore, cooperation between local authorities and citizens becomes essential for the success of the energy transformation, while providing a model of social and economic sustainability for Europe's energy future.

The transition towards renewable energy sources gives rise to a number of challenges that will need to be addressed if a sustainable energy future is to be achieved. These challenges are inherent to the process of shifting towards a more sustainable energy system, and must therefore be acknowledged and addressed.

Cetković et al. (2016) conduct an in-depth analysis of how renewable energy policies interact with different economic models across the EU. Their focus lies particularly on Germany's Coordinated Market Economy (CME), the UK's Liberal Market Economy (LME), and the Dependent Market Economies (DME) of Central and Eastern Europe, illustrating how diverse economic systems shape the trajectory of renewable energy transitions. [1]

Similarly, the Marinaș et al. (2018) explores the connection between renewable energy consumption and economic growth in Central and Eastern European (CEE) countries. Their findings indicate that an increased share of renewable energy positively impacts economic growth, a relationship comparable to the effects of investments in research and development (R&D) and human capital. This underscores the potential of renewable energy as a catalyst for broader economic development. [2]

According to Senpong et al. (2019), identifying political obstacles and implementing effective management practices are essential in achieving the transition to renewable energy. [3]

Child et al. (2019) highlight the role of flexible electricity generation, cross-border grid exchanges, and energy storage in achieving a 100% renewable energy system across Europe. They stress the importance of innovative approaches to address the technical challenges of integrating renewable energy sources into existing energy grids, emphasizing the need for adaptability and technological advancement. [4]

Meanwhile, Pérez et al. (2019) analyze the concept of a multi-speed energy transition within the EU, where member states progress at varying rates toward renewable energy adoption. Their study delves into the opportunities this uneven pace presents for enhancing EU energy security, as well as the challenges it poses in creating a unified energy strategy across diverse national contexts. [5]

In parallel, Ringrose (2020) emphasizes the importance of engineered geological storage for carbon dioxide (CO2) as a critical component in reducing greenhouse gas emissions and expanding renewable energy use. Such strategies are pivotal in mitigating the environmental impact of fossil fuel use, while also facilitating the integration of renewables. [6]

Eras-Almeida et al. (2020) focus on a specific example, analyzing efforts to decarbonize the Galapagos Islands through a hybrid renewable mini-grid system. Hoicka et al. (2020) provide practical policy guidance for the successful implementation of Renewable Energy Communities (RECs) as part of the EU's Renewable Energy Directive (RED II). They underscore the importance of grassroots engagement, community collaboration, and the social dimensions of energy policy in accelerating the renewable energy transition. As the European Union persists in its endeavors to advance decarbonization and pioneering climate policies, it encounters both challenges and prospects along its trajectory towards a future defined by renewable energy sources (Hafner et al., 2020). [7][8][9]

Meanwhile, Murombo (2021) addresses the regulatory challenges in South Africa's energy sector, where the balance between environmental sustainability, social equity, and economic growth presents unique complexities. His analysis sheds light on the difficulties faced by developing nations in their energy transitions. On the technical front, Capitanescu (2021) evaluates the issue of reactive power scarcity during the transition towards a 100% renewable energy supply highlighting the need for sophisticated grid management solutions as renewable energy sources becomes more prevalent. It is of the utmost importance to gain insight into the current state of renewable energy development in EU member states (Brodny et al., 2021) and to optimize sustainable renewable energy supply chains (Potrč et al., 2021) in order to guarantee a gradual but effective transition towards a fully renewable energy system by 2050. [10][11][12] [13]

In addition to political and technological challenges, the transition to renewable energy has important social and economic implications. Sulich et al. (2022) explore business management strategies related to energy transition, providing both theoretical contributions and practical recommendations for managing the transition within corporate structures. In the West African context, Ballo et al. (2022) review legal and policy frameworks designed to encourage investment in renewable energy, particularly green hydrogen, across ECOWAS countries, underscores the importance of creating consistent legal instruments to attract investments in clean energy technologies. [14][15]

Zakeri et al. (2022) further build on this by proposing policy recommendations aimed at overcoming obstacles in establishing resilient and sustainable energy systems, with a focus on optimizing energy services. [16]

In a related context, Dupont et al. (2023) discuss the European Green Deal (EGD) as a transformative policy framework designed to guide the EU toward achieving climate neutrality by 2050. [17]

Litră et al. (2023) explore the challenge of ensuring energy independence for the EU by promoting the use of renewable energy across various sectors, such as transportation and household electricity and highlights the significance of reducing the EU's reliance on imported energy sources by tapping into the region's own renewable energy resources. [18]

Karlilar et al. (2023) delve into the impact of research and development (R&D) investments on the financial performance of renewable energy firms within the EU. Their study examines how factors like shareholder protection and creditor rights influence the effectiveness of R&D investments, shedding light on the importance of robust regulatory frameworks in fostering innovation. Wojciechowski et al. (2023) turn their attention to the role of nuclear energy in the EU's low-carbon energy transition. Using panel data analysis, they investigate the determinants of greenhouse gas emissions and evaluate how nuclear energy contributes to climate change mitigation efforts. [19][20]

Jakubelskas et al. (2023) emphasize the critical role of adopting circular economy practices in the renewable energy sector as a means to achieve the Sustainable Development Goals (SDGs). Their research suggests that this approach is essential for European Union (EU) member states to meet the ambitious targets outlined in the Paris Agreement and to effectively tackle the challenges associated with climate change. Circular economy principles, which focus on minimizing waste and maximizing resource efficiency, offer a pathway for EU countries to balance economic growth with environmental sustainability. Lastly, Nitte (2023) examines the global energy transition's impact on Nigeria's energy security, emphasizing the necessity of diversifying energy sources and promoting equity as the country works towards achieving net-zero emissions. [21][22]

The transition to renewable energy represents a complex, multidimensional process necessitating coordinated efforts across a range of domains, including politics, regulation, technology, and social structures. The manuscript highlight the need for innovative policy solutions, increased investments in research and development, and the integration of circular economy principles to expedite the shift toward a more sustainable and resilient energy system in the EU.

2. Data and Methodology

Analyzing the challenges and opportunities associated with the renewable energy transition in Europe is a dynamic and evolving research topic, particularly relevant in the context of the ongoing transformation of the energy paradigm. This study explores these aspects through a structured approach that focuses on the European Union's efforts to meet its renewable energy targets and better understand the implications of this shift within the framework of newly implemented policy initiatives. By employing a combination of quantitative and qualitative research methods, the study provides a comprehensive assessment of the progress, obstacles, and policy outcomes related to renewable energy adoption across EU member states.

The research is organized into two main sections. The first section analyzes the progress of the EU member states in achieving their renewable energy targets, comparing the renewable energy shares (RES-shares) for 2020, 2021, and projected figures for 2030. The second section evaluates the ongoing transformation of the energy paradigm, considering new policy efforts aimed at promoting sustainability and reducing dependence on fossil fuels. To offer a deeper understanding of the possible future scenarios, the study examines energy consumption trends across several policy scenarios, such as Baseline, Regulatory, Carbon Pricing, MIX-50, and ALLBNK. These scenarios provide insights into the potential outcomes for the EU's energy system by 2030 and 2050.The primary data sources for this research include Eurostat's 2023 data on the share of energy from renewable sources, national RES-

shares for 2020 and 2021, and projections for 2030. Additionally, reports from the European Commission (2020, 2023) were used to gather information on energy consumption trends, national energy and climate plans (NECPs), and subsidy distributions among different energy carriers.

The research synthesizes findings from various academic studies and policy analyses on renewable energy policies, economic models, and technological innovations that are shaping the energy transition in different EU countries. By integrating these findings, the study identifies the factors that facilitate or hinder renewable energy adoption and provides recommendations for enhancing policy frameworks and investment strategies to accelerate the transition.

The study involved analysis of secondary data on RES-shares for each EU member state and the comparative analysis highlights the current achievements of member states, identifies gaps in ambition, and evaluates their capacity to align with the EU's overarching renewable energy goals. In doing so, the research offers a view of the ongoing transformation of the European energy landscape, underscoring the critical need for coordinated policy interventions, increased investment, and regional cooperation to ensure a sustainable and resilient energy future for the European Union.

3. Results and Discussion

3.1. Challenges and opportunities on promotion of renewable energy development in European Union

The transition to renewable energy represents a central component of the global response to climate change, with the objective of reducing reliance on fossil fuels. The European Union (EU) has assumed a proactive role in this transition, with the establishment of ambitious targets to enhance the proportion of renewable energy in its total energy consumption by 2030. In figure 1 is presented the Share of energy from renewable sources in 2022 and the target for 2030.

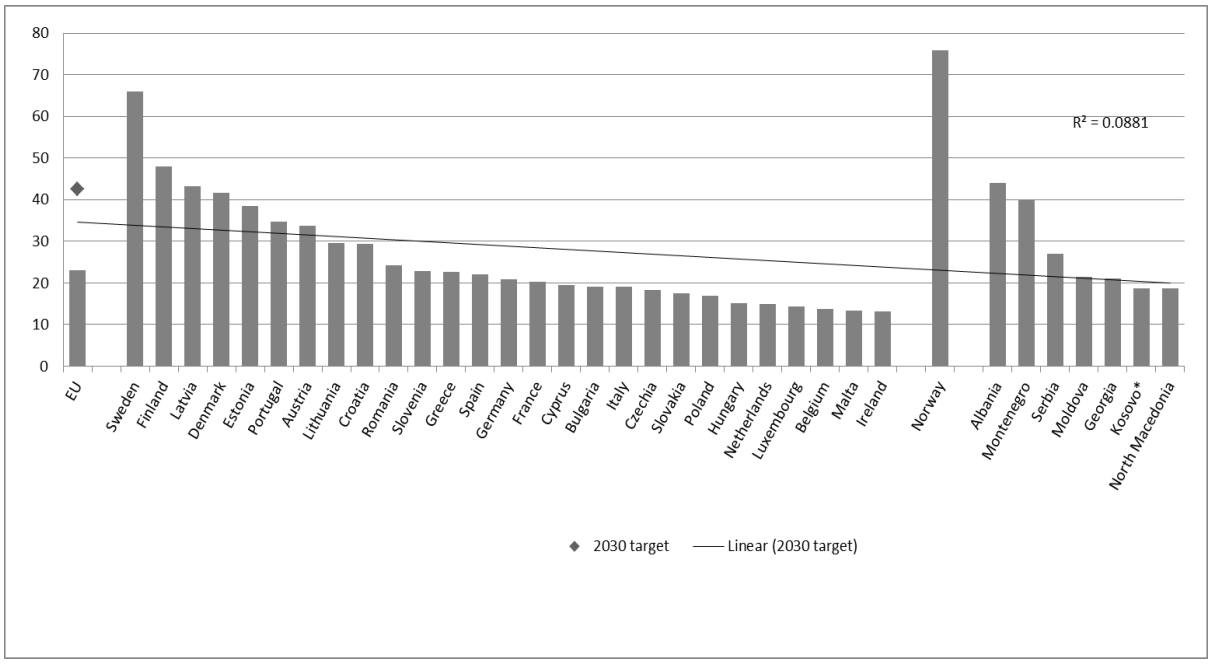

Figure 1. Share of energy from renewable sources, 2022 (%) Source: Eurostat, 2023. [23]

The European Union (EU) has established a series of ambitious targets for the utilization of renewable energy sources with the objective of combating climate change and promoting sustainability. As part of its integrated strategy, the EU has set a target of achieving a minimum of 42.5% renewable energy consumption by 2030. The transition to renewable energy, however, presents a number of significant challenges for member states, with varying levels of success in meeting national binding targets and aligning with the overarching Union goal. This article tries to provide a scientific analysis of the performance of EU member states based on a comparative table outlining their renewable energy shares (RES-shares), current achievements, projected contributions, and ambition gaps relative to the 2030 targets.

According to figure 1 countries like: Sweden, Finland, and Norway stand out as leaders in renewable energy adoption. According to the 2022 data, Sweden had the highest share of renewable energy in Europe, exceeding 70%, with Finland and Norway following closely. This success can be attributed to several key factors. Firstly, these countries have made significant investments in renewable energy infrastructure, particularly in hydropower. Norway, for instance, derives the majority of its electricity from hydropower, thanks to its abundant water resources and favorable topography. Sweden and Finland also benefit from extensive use of hydropower, as well as significant investments in wind and bioenergy. Secondly, supportive government policies have played a crucial role in fostering renewable energy growth. Sweden's carbon tax, introduced in the 1990s, has been a critical driver of its renewable energy transition by incentivizing the use of cleaner energy sources. Similarly, Norway's early adoption of green energy policies and its significant revenues from fossil fuel exports have allowed it to invest heavily in renewable energy technologies.

Geography also provides a distinct advantage to these nations. Their vast natural resources, coupled with a relatively small population, create a unique environment where renewable energy can thrive. For countries like Sweden, Finland, and Norway, the challenge moving forward will be to maintain and expand their renewable energy infrastructure while continuing to lead by example in global climate initiatives.

A number of EU member states, including Denmark, Estonia, Portugal, Austria, and Spain, have made notable progress in increasing their renewable energy share, with figures ranging between 30% and 50% in 2022. These middle-ranking countries reflect varying degrees of success and challenges.

However, countries such as Spain and Greece, despite having abundant solar resources, have not fully capitalized on their potential. The slower pace of renewable energy adoption in these countries can be linked to economic challenges and a lack of sufficient investment in renewable energy infrastructure. The global financial crisis of 2008 had a lasting impact on public spending in these nations, limiting their ability to invest in large-scale renewable projects. Despite these setbacks, Spain and Greece have made progress in recent years, driven by the EU's push for green energy and renewed interest in solar energy as costs continue to fall.

At the lower end of the spectrum, countries like Belgium, Ireland, Poland, and Luxembourg have renewable energy shares below 20%. For these nations, the transition to renewable energy has been more challenging due to a combination of structural, economic, and political factors. Belgium, for example, has faced difficulties in expanding its renewable energy capacity due to its densely populated landscape, which limits the available space for large-scale wind or solar farms. Moreover, political divisions between its regions have led to fragmented energy policies, making it harder to achieve cohesive national strategies. Ireland, despite its vast potential for wind energy, has struggled with regulatory and grid infrastructure issues, which have slowed the pace of new renewable installations.

Poland presents a particularly stark case, as its economy remains heavily reliant on coal. Coal mining is not only a major economic driver in Poland but also a politically sensitive issue due to the large number of jobs it provides. Transitioning away from coal and toward renewable energy will require substantial financial support from the EU, as well as a careful balancing of economic and environmental priorities. Similarly, other Central and Eastern European countries face similar obstacles in overcoming historical dependence on fossil fuels and catching up with their Western European counterparts.

One of the major challenges for lower-performing countries is the need for substantial investment in renewable energy infrastructure. Countries like Poland, Belgium, and Ireland will require significant financial resources to upgrade their energy grids, expand renewable energy capacity, and phase out coal and other fossil fuels. The EU has made funds available for these transitions, but the effective use of these resources will depend on the political will and administrative capacity of individual member states. Another key challenge is the development of energy storage technologies.

Table 1 provides a systematic overview of the renewable energy shares (RES-shares) of European Union (EU) member states in 2020 and 2021, along with projected contributions by 2030. This is set in the context of the EU-wide target of at least 42.5% renewable energy consumption by 2030. Furthermore, the table identifies the ambition gaps of each country, which represent the discrepancy between the national targets and the shares that must be achieved to meet the EU-wide goals.

Table 1. National contributions and ambition gaps towards the Union target of at least 42.5% of renewable energy consumption. RES Shares.

	2020 national binding target	2021 national shares value	2030 national contribution (as per draft updated NECP)	2030 shares in line with the formula	Ambition gap
AT	34%	36.4%	46%-50%	57%	Significantly below
BE	13%	13.0%	21.7%	33%	Significantly below
BG	16%	17.0%	29.9%	33%	Below
CY	13%	18.4%	26.5%	33%	Significantly below
CZ	13%	17.7%	30%	33%	Below
DE	18%	19.2%	40%	41%	Slightly below
DK	30%	34.7%	70.9%	60%	Significantly above
EE	25%	38.0%	65%	50%	Significantly above
EL	18%	21.9%	44%	39%	Significantly above
ES	20%	20.7%	47.9%	43%	Above
FI	38%	43.1%	51%	62%	Significantly below
FR	23%	19.3%	33%	44%	Significantly below
HR	20%	31.3%	42.5%	44%	Slightly below
HU	13%	14.1%	29%	34%	Significantly below

IE	16%	12.5%	31.4%-34.1%	43%	Significantly below
IT	17%	19.0%	40.5%	39%	Slightly above
LT	23%	28.2%	55%	49%	Significantly above
LU	11%	11.7%	37%	37%	In line
LV	40%	42.1%	57%	61%	Significantly below
MT	10%	12.2%	11.5%	28%	Significantly below
NL	14%	13.0%	27%	39%	Significantly below
PL	15%	15.6%	23%-31%	32%	Significantly below
PT	31%	34.0%	49%	51%	Slightly below
RO	24%	23.6%	34%	41%	Significantly below
SE	49%	62.6%	65%	76%	Significantly below
SI	25%	25.0%	30%-35%	46%	Significantly below
SK	14%	17.4%	23%	35%	Significantly below

Source: European Commission (2023) [24]

A number of countries have demonstrated remarkable progress in exceeding their renewable energy targets. Denmark (DK), for instance, has demonstrated a consistent leadership position in the renewable energy transition. It is projected that Denmark's renewable energy share will reach 70.9% by 2030, which is well above the required share of 60%. Denmark's success can be attributed to a combination of factors, including a robust investment in wind energy, both onshore and offshore, as well as progressive energy policies that have encouraged the development of large-scale renewable infrastructure. Similarly, Estonia (EE) is projected to achieve a 65% renewable energy share by 2030, which is considerably in excess of the target of 50%. Estonia's robust performance is indicative of its dedication to diversifying its energy sources and reducing its reliance on fossil fuels, particularly oil shale. It is similarly anticipated that Lithuania (LT) and Greece (EL) will markedly exceed their established targets, thereby exemplifying the efficacy of their renewable energy strategies and investments.

Luxembourg (LU) is the sole country in the table for which the projected alignment with the target is absolute. It is anticipated that by 2030, Luxembourg will have achieved a 37% renewable energy share, which is precisely in accordance with the target calculated using the EU formula. This degree of alignment suggests that Luxembourg has meticulously calibrated its renewable energy policies and investments in order to fulfil its obligations as set forth in the Renewable Energy Directive.

A number of countries, including Germany (DE) and Italy (IT), are on course to meet their 2030 renewable energy targets, although they have yet to achieve the requisite shares. Germany is projected to achieve a 40% renewable energy share by 2030, which is just below the 41% target. Despite its status as a global leader in renewable energy, particularly in solar and wind power, Germany encounters

obstacles pertaining to grid stability, energy storage, and the phase-out of nuclear power. These challenges impede its ability to achieve the EU's ambitious goals. In contrast, Italy is projected to exceed its 39% target, reaching 40.5% by 2030. Italy's progress has been driven by substantial investments in solar power and hydropower. However, challenges remain, including grid integration and regional disparities in renewable energy production.

A number of countries are currently failing to meet the ambitious targets set for renewable energy contributions by 2030. For instance, Belgium (BE) is projected to reach a mere 21.7% renewable energy by 2030, a figure that falls significantly below the required 33%. The underperformance of Belgium is indicative of its continued reliance on fossil fuels and nuclear power, in addition to a slower deployment of renewable energy infrastructure. France (FR) is another major economy that is experiencing difficulties in meeting its renewable energy targets. With a projected 33% share by 2030, France is significantly below the required 44%. Despite France's status as a global leader in nuclear energy, its renewable energy transition has been slower than anticipated due to challenges in expanding wind and solar capacity and integrating these technologies into its energy mix.

It is similarly anticipated that countries such as Ireland (IE), the Netherlands (NL), and Sweden (SE) will fail to meet their 2030 targets to a considerable extent. Ireland is projected to reach a 31.4%–34.1% share, which is well below the 43% target. The Netherlands, with a projected share of 27%, falls significantly short of its 39% target, reflecting a gradual transition away from natural gas. Notably, despite Sweden's commendable renewable energy performance in 2021 (62.6%), it still faces an ambition gap due to the ambitious 2030 target of 76%.

The bar chart in the upper section of the figure bellow shows the total energy consumption measured in gigatons of oil equivalent (Gtoe). The historical data for 2000 and 2015 reveal a relatively stable energy demand, with values hovering around 1.4 Gtoe. This suggests that energy consumption did not grow significantly during the early 21st century, possibly reflecting improvements in energy efficiency alongside economic growth.

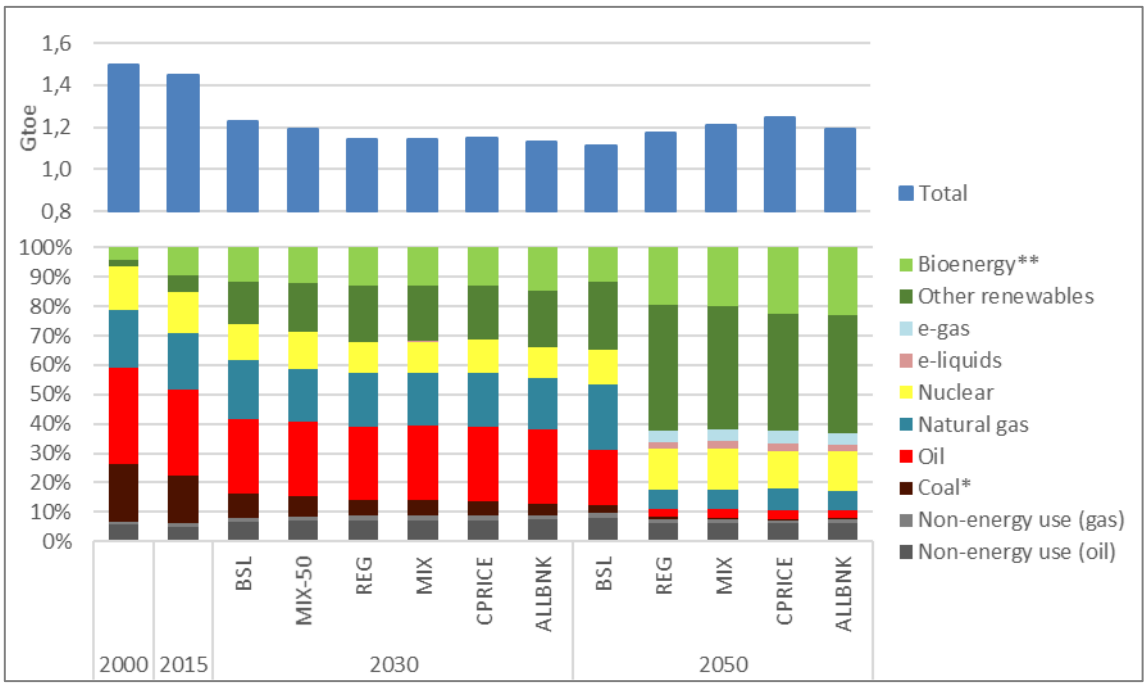

Figure 2. Energy gross inland consumption Source: European Commission (2020). [25]

Projections for 2030 and 2050 show a gradual reduction in total energy consumption across all scenarios, signaling the influence of energy efficiency measures and the decoupling of energy

consumption from economic output. The steepest reductions are observed in the REG (Regulatory) and CPRICE (Carbon Pricing) scenarios, where stringent decarbonization policies are assumed. This decline reflects both efficiency gains and reduced fossil fuel consumption in favor of renewable energy sources.

In contrast, more moderate reductions are projected in the MIX-50 and ALLBNK scenarios, which also assume a transition toward cleaner energy but with less aggressive energy-saving measures. This indicates that energy demand can be better managed with strong policy intervention, while less stringent scenarios may result in higher overall consumption due to continued reliance on fossil fuels. In both 2000 and 2015, the global energy system was dominated by fossil fuels—primarily oil, coal, and natural gas—which together accounted for the majority of the energy mix. In particular, oil use was prominent, driven by demand in transportation, while coal played a significant role in power generation. Nuclear energy contributed a small but stable share, whereas renewables (bioenergy and other renewables) were still marginal in terms of their overall contribution.

By 2015, some decline in coal use can be observed, reflecting the early impacts of global climate policies and the phasing out of coal in some economies. However, despite the growth of renewables, fossil fuels continued to dominate, illustrating the challenges in transitioning to a cleaner energy mix.

In 2030, the energy mix begins to show a more noticeable shift toward renewables under all scenarios. The share of bioenergy and other renewables (such as solar and wind) increases across the board, though the rate of change depends heavily on the specific scenario: In the Baseline (BSL) scenario, fossil fuels remain a significant part of the energy mix, though renewables make modest gains. This reflects a "business-as-usual" scenario with limited policy intervention, suggesting that without strong measures, fossil fuels will continue to play a central role. The MIX-50 and REG scenarios exhibit faster adoption of renewables, with bioenergy and other renewables comprising nearly 40% of the energy mix. In the CPRICE and ALLBNK scenarios, fossil fuels are sharply reduced, with bioenergy and renewables making up close to half of the energy mix. These scenarios assume stringent carbon pricing and ambitious decarbonization policies, reflecting a clear shift away from fossil fuels.

By 2050, all scenarios project a further reduction in fossil fuel use, though the extent of the transition depends on the policy measures enacted:

- The BSL scenario continues to show significant reliance on natural gas and oil, indicating that without more ambitious policies, fossil fuels will still represent around half of the energy mix by mid-century. This underscores the need for policy reforms to drive the transition toward clean energy.
- In the REG, MIX, CPRICE, and ALLBNK scenarios, renewables (bioenergy and other renewables) dominate the energy system, accounting for over 60% of the energy mix in most cases. Bioenergy becomes particularly important, especially in harder-to-decarbonize sectors such as heating and transportation. The near-complete phase-out of coal in most scenarios by 2050 highlights the success of global efforts to move away from this high-emission energy source. Natural gas and oil continue to play a role, though their share is significantly reduced, particularly in the CPRICE and ALLBNK scenarios.
- The emergence of e-gas and e-liquids—synthetic fuels produced using renewable energy—indicates the role of new technologies in achieving deep decarbonization, especially for sectors like heavy industry and aviation that are harder to electrify.

3.2. Financing the distribution of subsidies by main energy sources

The figure 2 illustrates the distribution of subsidies by main energy sources and energy carriers in the European Union (EU27) from 2015 to 2022, measured in billions of euros (EUR2022). It categorizes subsidies into five key sectors: fossil fuels, renewable energy sources (RES), electricity, nuclear energy, and all energies. The growth of overall subsidies and the shifting focus of EU energy policy can be clearly observed over this period.

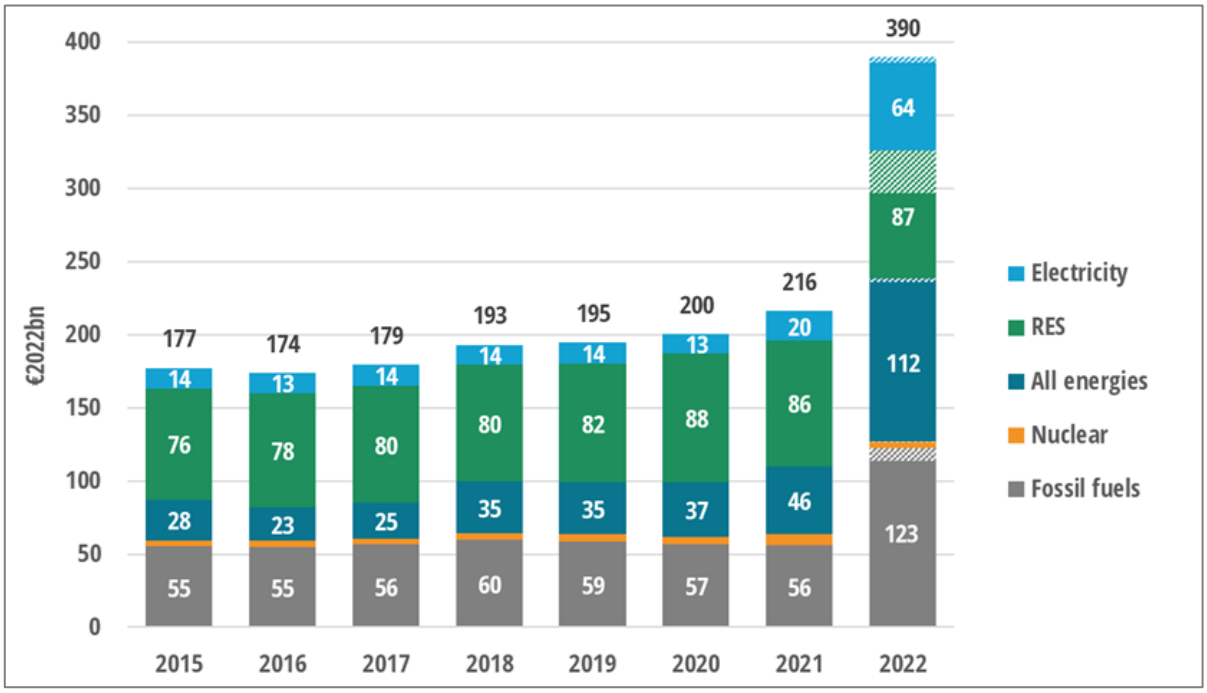

Figure 3. Subsidies by main energy source / energy carrier in the EU27 (2015-2022; EUR2022bn)
Source: European Commission (2023a). [26]

The data presented in the figure above highlights a dramatic increase in overall energy subsidies in 2022, rising to EUR 390bn compared to the more stable range of EUR 174bn to EUR 216bn in previous years. This sharp rise is driven by the dual pressure of ensuring immediate energy security and mitigating the effects of the global energy crisis, while simultaneously maintaining momentum towards the EU's long-term renewable energy goals.

Throughout the observed period, fossil fuels consistently received substantial subsidies, with a range of EUR 55bn to EUR 60bn annually from 2015 to 2021. However, 2022 saw a marked increase to €123 billion, representing a more than twofold increase relative to the previous year's allocation. This surge can be attributed primarily to the energy crisis that ensued following Russia's invasion of Ukraine, which precipitated substantial disruptions in the global energy supply, particularly in gas markets. The rise in subsidies is indicative of the EU's recognition of the necessity to guarantee energy security and to stabilize energy prices for consumers, even if this is at odds with the EU's long-term objective of reducing its reliance on fossil fuels.

The subsidies allocated to renewable energy sources exhibited a gradual increase from 2015 to 2020, reaching a total of EUR 88 billion. However, in 2021, there was a slight decline in this figure. However, the year 2022 saw a considerable increase in renewable energy subsidies, reaching a total of EUR 112 billion. The level of subsidies allocated to nuclear energy remained consistent throughout the observed period, with a range of EUR 13bn to EUR 14bn annually. This consistent level of support demonstrates the EU's measured approach to nuclear energy, which, despite its low-carbon characteristics, remains a topic of contention due to concerns about nuclear waste management and safety risks. While some EU member states, such as France, advocate for an increased reliance on nuclear power, the overall level of subsidies suggests that it is not a primary focus of EU energy policy compared to renewables.

The level of electricity subsidies remained relatively stable from 2015 to 2020, with a slight fluctuation between EUR 13 billion and EUR 14 billion. However, there was a notable increase in these subsidies in 2021 (EUR 20bn) and a further substantial increase in 2022, reaching EUR 64bn. The considerable increase observed in 2022 can be attributed to the European Union's initiatives to stabilize the electricity market in response to the prevailing energy crisis. The increase in electricity subsidies is

likely to reflect government interventions, such as the imposition of price caps or the provision of direct consumer support, which have been implemented with the objective of protecting households and businesses from the adverse effects of rising electricity prices.

The evolving pattern of subsidies demonstrates the EU's attempts to reconcile short-term energy security with long-term sustainability. While the surge in fossil fuel subsidies in 2022 was a direct response to the acute energy crisis, the augmented support for renewable energy sources indicates that the EU remains firmly committed to its climate and energy transition objectives. The principal challenge for the EU in the future will be to phase out fossil fuel subsidies in favor of renewables, while ensuring that energy prices remain stable and energy security is not compromised.

The considerable increase in fossil fuel subsidies in 2022 was a necessary short-term measure to mitigate the effects of the energy crisis. However, it also serves to highlight the need for greater energy independence and resilience in the longer term. The growing investment in renewable energy sources, particularly in 2022, reflects the EU's broader strategy to achieve net-zero emissions by 2050. In order to achieve this long-term commitment, it is necessary to continue increasing renewable subsidies and to develop supportive infrastructure, such as smart grids and energy storage systems.

Conclusions

The transition to renewable energy across the European Union is proceeding at varying rates. While some member states are making significant progress and exceeding their targets, others are struggling to meet their ambitious goals. The analysis demonstrates that countries with robust policy frameworks, advantageous geographic conditions, and resilient energy infrastructure are more likely to achieve or exceed their 2030 targets. While countries such as Denmark, Estonia and Lithuania are well on course to exceed their 2030 targets, others, particularly in Western and Central Europe, face significant gaps in ambition. In order to achieve the EU-wide goal of 42.5% renewable energy consumption by 2030, it is essential that lagging countries accelerate their renewable energy deployments through targeted policy interventions, increased investments, and enhanced regional cooperation. Nevertheless, numerous countries continue to confront significant challenges, including inadequate grid capacity, public opposition, and policy deficiencies. To accomplish the EU's ambitious renewable energy objectives, member states must expedite their initiatives, invest in infrastructure, and adopt innovative strategies to surmount these impediments. The transition to renewable energy sources is fundamental not only for achieving climate goals but also for ensuring the long-term energy security and sustainability of the European Union.

Limitations and further research directions

This research faces several limitations, primarily related to the availability of updated national energy and climate plans (NECPs) from EU member states. The study does not delve into country-specific political or socio-economic contexts that may influence the renewable energy transition, focusing instead on aggregate data and trends. Future research could address these gaps by incorporating more localized data and conducting case studies to better capture the diversity of political and socio-economic contexts within the EU that impact the pace and success of the renewable energy transition.

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