PROMOTING RENEWABLE ELECTRICITY: TARGETS; STRATEGIES, BY TECHNOLOGY

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Abstract

The transition to renewable electricity is vital for combating climate change and establishing sustainable energy systems. This study investigates the promotion of renewable electricity in the European Union (EU), Austria, and the Czech Republic through targets, strategies, and technologies.

Firstly, the main reasons why electricity from renewable energy sources should be promoted, are analyzed with a focus on the issues given by energy insecurity and greenhouse gas emissions. The main challenges and barriers for the development of renewable electricity are also illustrated.

The study focuses then on three main key drivers for renewable energy deployment: targets, strategies and technologies, and it underlines how a comprehensive and integrative approach which combines these three main pillars is needed to promote renewable electricity. The EU's binding targets presented by the Renewable Energy Directive are playing a crucial role in the transition to renewable energy and they are pushing the member states to adopt specific national targets in terms of renewable electricity share. Regarding the strategies, this study investigates the most important policy frameworks, cooperation mechanisms and plans of action suggested by the European Commission to the member states. A lot of relevance is also given to the supporting schemes which can be freely adopted by the single countries, such as carbon policies and generation, investment and quantity supports. The EU's technology-neutral approach allows countries to adopt suitable renewable energy technologies based on their resource availability, geographical location and policy framework. Wind power, solar photovoltaic (PV) systems, hydropower, biomass, and geothermal energy are prominent technologies employed extensively in European nations.

All these topics in the European Union are presented, especially in Czech Republic and Austria in order to provide a comparison based on the ways in which the two different countries are increasing and promoting their renewable electricity shares. The national targets, the national support schemes and the different technologies used by the two countries as sources of electricity are analyzed and discussed in depth.

Keywords: renewable electricity, decarbonization targets, renewable electricity policies, renewable electricity technologies, decarbonization strategies, Austria, Czech Republic.

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1. Introduction

Renewable energy sources have become a crucial topic in the global effort to reduce carbon emissions and combat climate change. Electricity is playing a crucial role more than ever in modern societies with its expansion in transport and heating through technologies such as electric vehicles and heat pumps. Also, the recent energy crisis has contributed to make electricity security and affordability a priority. These are the reasons why countries and organizations worldwide have set ambitious targets for increasing the use of renewable electricity. The European Union, Czech Republic, and Austria have taken significant steps in promoting renewable electricity by implementing various targets and strategies and by using different technologies to achieve their goals.

The European Union has set a target of achieving at least 32% renewable energy share in its final energy consumption by 2030 and it is also addressing the challenge of high electricity prices given by the uncertainties regarding gas supply. Along with the high cost of electricity generation, the world's power systems also faced challenges from extreme weather events in 2022 such as the drought conditions which led to a drop in hydropower generation which highlighted the importance of increasing security of supply and resilience. To deal with these challenges, the EU has implemented a range of strategies, including financial support for renewable energy projects, policy and regulatory frameworks, and research and innovation initiatives to promote the usage of electricity from renewable energy sources. As the share of variable renewables increases in the generation fleet, their successful integration into the power system will increasingly become more challenging. For the balancing of variable generation, apart from expanding storage capacities and increasing demand-side flexibility, having sufficient dispatchable capacity will be crucial [6].

1.2. Why promote renewable electricity?

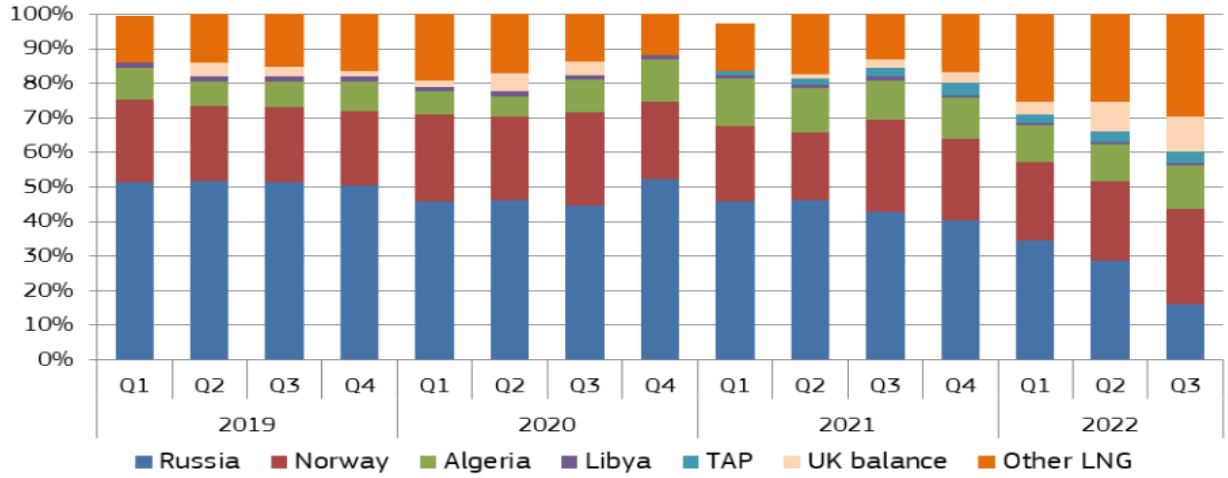
Promoting renewable electricity in the European Union (EU), Czech Republic (CZ), and Austria is essential for several reasons. Firstly, renewable electricity helps to reduce greenhouse gas emissions and mitigate climate change. By using renewable energy sources such as wind, solar, and hydropower, the EU, CZ, and Austria can decrease their reliance on fossil fuels, which are the primary source of greenhouse gas emissions. Secondly, promoting renewable electricity can improve energy security and independence. The EU, CZ, and Austria rely heavily on imported fossil fuels, which can be affected by geopolitical tensions, price volatility, and supply disruptions. By investing in renewable energy, these countries can reduce their dependence on foreign energy sources and enhance their energy security. In the next subsections, these reasons and the limitations to promoting renewable electricity are explained in detail.

1.2.1. Energy insecurity

Promoting renewable electricity plays a crucial role in reducing energy insecurity for several reasons. Firstly, renewable energy sources such as solar, wind, hydro, and biomass offer a diverse and decentralized energy supply. Unlike fossil fuels, which are often concentrated in specific regions or countries, renewable energy resources can be harnessed across various geographical locations. This distributed nature of renewable electricity generation enhances energy security by reducing dependence on a limited number of energy sources or suppliers.

Secondly, renewable electricity contributes to the diversification of the energy mix. By reducing reliance on fossil fuels, which are finite and subject to price volatility, renewable energy sources provide a stable and sustainable alternative. This diversification helps mitigate the risks associated with energy price fluctuations and supply disruptions, reducing vulnerability to geopolitical tensions and external shocks. The European Union (EU) is heavily dependent on energy imports, making it vulnerable to geopolitical risks and fluctuations in energy prices. The EU imports around 53% of its energy needs, with natural gas, crude oil, and coal being the primary sources; the shares of gas import of the EU countries from extra-EU

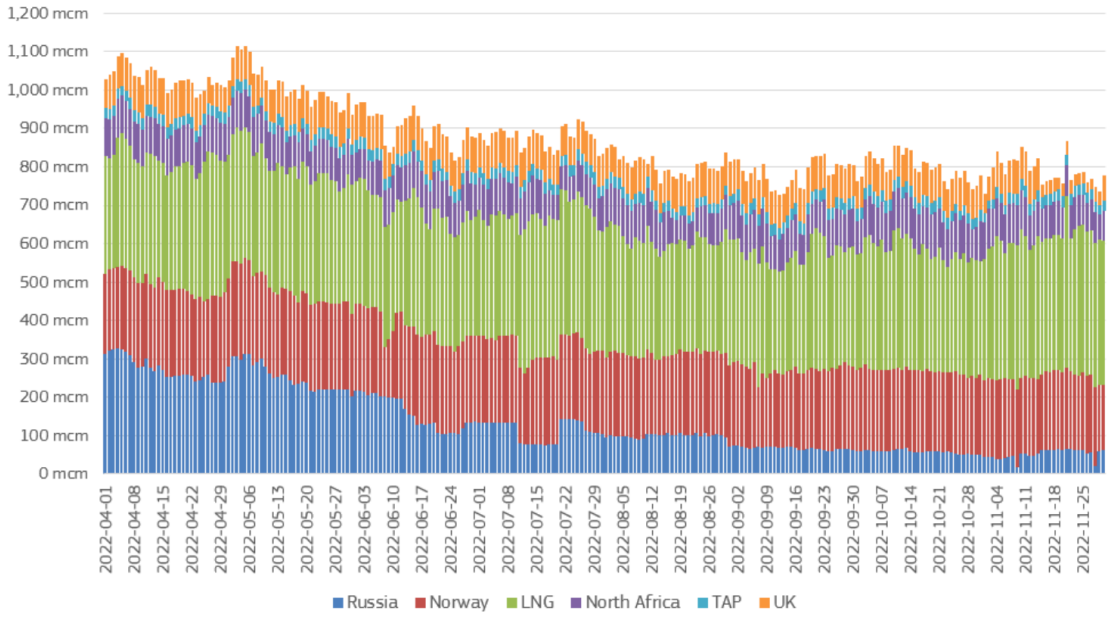
countries are presented in Figure 1. This high level of energy dependence poses significant economic and security challenges for the EU, making it imperative for the region to address the issue [12].



Source: Based on data from the ENTSO-G Transparency Platform, data as of 2 December 2022.

Figure 1 Share of EU27 countries gas import within the total, both pipeline and LNG imports

As it is possible to see in Figure 1, the role of Russian gas imports in the European Union (EU) has undergone a remarkable transformation over the last couple of years. In January 2021, Russia was responsible for supplying around 53% of the total extra-EU gas imports through pipeline and LNG supplies. However, in November 2022, this share dropped to barely 13%, marking a significant shift in the EU's energy supply landscape. Figure 2 shows the EU daily imports of natural gas in million cubic meters from the main extra-EU gas exporters, highlighting even more how the daily inflow from Russia stabilized at very low levels in October and November 2022.



Source: Based on data from the ENTSO-G Transparency Platform, data as of 2 December 2022.

Figure 2 EU27 daily imports of natural gas by source [12]

The high decrease of daily inflow of gas from Russia is directly connected to the Russian invasion of the Ukraine and it has led to a significantly increase of gas prices. Figure 3 shows the wholesale day-ahead gas prices on gas hubs in the EU, evidencing a high peak in the second semester of 2022. The energy insecurity emerged by this scenario, has led to the REPowerEU plan, which aims to phase out fossil energy imports from Russia and other non-EU countries. The plan seeks to increase the EU's energy independence and reduce its reliance on non-renewable energy sources, including gas imports from Russia in order to reduce energy insecurity and to keep energy prices stable [12].

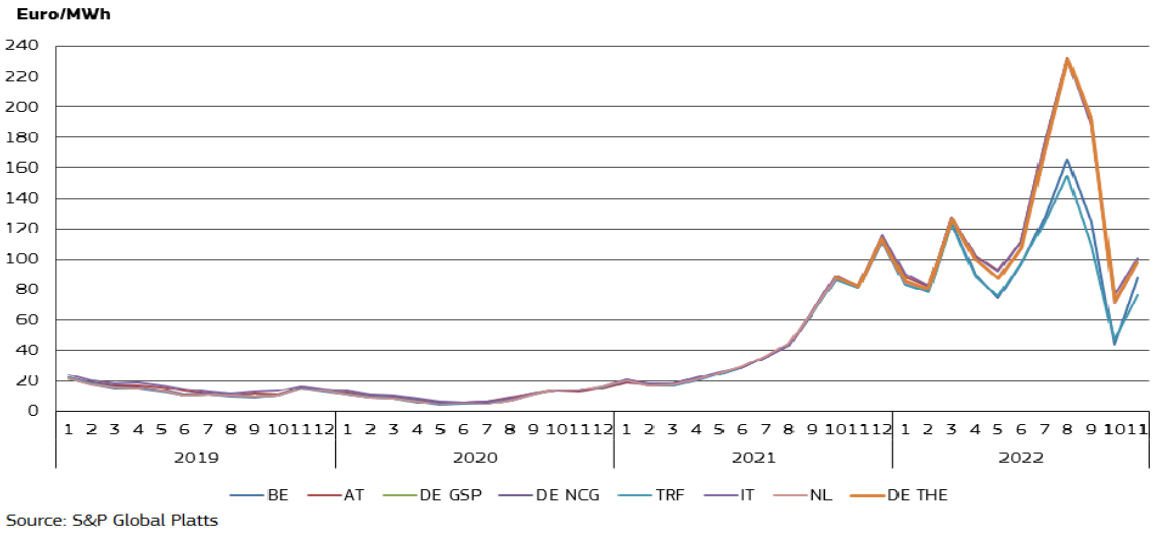


Figure 3 EU wholesale day-ahead gas prices development on gas hubs [12]

Furthermore, promoting renewable electricity fosters the development of local economies and job creation. The deployment of renewable energy technologies requires investments in manufacturing, installation, and maintenance, leading to the establishment of new industries and employment opportunities. This economic diversification enhances the resilience of communities and reduces their dependence on external energy sources, thus strengthening energy security at the local level.

Lastly, renewable electricity promotes energy self-sufficiency and energy independence. By harnessing indigenous renewable resources, countries can reduce their dependence on imported energy resources, which are often subject to geopolitical risks and price fluctuations. This enhanced energy self-sufficiency contributes to a more secure and stable energy supply, reducing vulnerabilities associated with external energy dependencies.

In summary, promoting renewable electricity is of paramount importance in reducing energy insecurity. It enhances energy diversity, reduces reliance on fossil fuels, increases resilience to climate change impacts, fosters local economic development, and promotes energy self-sufficiency. By embracing renewable energy sources, countries can achieve greater energy security and mitigate the risks associated with traditional energy systems.

1.2.2 Greenhouse gas (GHG) emissions

Promoting renewable electricity is crucial for significantly reducing greenhouse gas (GHG) emissions and addressing climate change. By replacing fossil fuel-based electricity generation with clean and sustainable renewable energy sources like solar, wind, hydro, and biomass, the release of GHGs, particularly carbon dioxide (CO_2), can be substantially curtailed [12]. This transition to renewable electricity plays a vital role in mitigating climate change by lowering the overall carbon footprint of the energy sector. The EU, as a

signatory to the Kyoto Protocol, committed to reducing its greenhouse gas emissions by 8% during the first commitment period, spanning from 2008 to 2012. The reduction target is distributed among the member states through a legally binding burden-sharing agreement, which defines individual emissions targets for each state. The Kyoto Protocol was ratified by the EU and all its member states on May 31, 2002 [13].

The Kyoto Protocol required the European Community to decrease its greenhouse gas (GHG) emissions by 8 percent between 2008 and 2012, taking 1990 as the reference level. Based on GHG emissions limitation or reduction commitments of EU Member States, the Czech Republic has a target to reduce 8% and Austria has 13% between 2008 and 2012[14] and the national emission targets for 2020 were agreed upon unanimously and were set based on member States' relative wealth ranging from a 20% emissions reduction by 2020 [15]. One of the mechanisms the EU introduced to reduce GHG is the directive of emission trading scheme which aims to reduce GHG emissions in a cost-effective way, including the introduction of GHG emissions ceilings and trading, and member States are responsible for allocating permits and therefore the total quantity of allowance (cap) to companies covered under the directive [14].

The integration of renewable energy into the grid and the electrification of sectors such as transportation and heating using renewable electricity further contributes to emissions reductions. Additionally, ongoing technological advancements and cost reductions in renewable energy make it an increasingly economically competitive and environmentally beneficial choice for electricity generation. In conclusion, promoting renewable electricity offers a powerful solution for reducing GHG emissions, mitigating climate change, and fostering a sustainable energy future.

1.2.3 Barriers and challenges

In this section, we examine the significant barriers that impede the deployment of renewable energy projects and hinder the increase of electricity generated from renewable energy sources.

One prominent barrier is the existence of government subsidies for fossil fuels. Fossil fuel subsidies are measures implemented to reduce fuel costs for consumers or increase the revenue received by energy producers. Such incentives limit the production of renewable energy and contribute to the sustained demand for fossil fuels. To facilitate the transition to renewable energy, it is essential to eliminate these subsidies and reallocate the resources towards renewable energy projects.

Another barrier arises from biases against renewable energy held by major conventional energy producers. They often criticize the use of renewable energy and portray it as expensive and unpredictable. Several studies, conducted in various capacities, undermine the deployment of renewable energy by arguing that it is incapable of meeting global energy demands. These biases have influenced public perception of renewable energy sources, affecting their perceived reliability, security, and affordability.

Cost unawareness among key stakeholders, such as large investors and governments, poses another barrier. Often, these stakeholders lack awareness of market changes within the renewable energy sector, resulting in decisions based on outdated perspectives. This institutional barrier delays the integration of renewable energy into the market and hampers its expansion.

Furthermore, some oil companies exhibit reluctance to diversify their portfolios, which acts as a barrier to the transition to renewables. Their resistance to embracing renewable energy sources hinders progress in achieving sustainable energy systems.

Grid connection presents another challenge for renewable energy investors. The lack of grid availability can deter financing for renewable energy projects. In situations where electricity production exceeds the

capacity of the existing grid infrastructure, the excess power may go to waste or only partially be purchased.

The intermittent nature of abundant renewable energy resources, such as solar and wind, necessitates the requirement for energy storage technologies to meet peak demand. Storage technologies are essential to address the variability of renewable energy production and ensure a stable and reliable electricity supply.

Technical and resource constraints also limit the deployment of renewable energy. Certain regions may have limited solar, wind, or hydroelectric resources, making it challenging to develop these technologies in those areas.

In summary, barriers to the deployment of renewable energy projects and the scaling up of renewable electricity generation include government subsidies for fossil fuels, biases against renewable energy, cost unawareness among stakeholders, resistance from oil companies, grid connection issues, energy storage requirements, and technical and resource constraints. Addressing these barriers is essential to promote the widespread adoption of renewable energy and facilitate the transition to a sustainable and low-carbon energy future.

2. Methodology

2.1. Current situation and technologies

2.1.1. Current situation and technologies in the EU

The electricity sector in the European Union (EU27) has undergone significant transformations in recent years, with a growing emphasis on renewable electricity generation and decarbonization. The EU27 countries have been actively pursuing the transition towards a more sustainable and low-carbon energy system, aiming to reduce greenhouse gas emissions and increase the share of renewable energy sources in the electricity mix.

The current situation of renewable electricity generation in the EU27 is promising. According to Eurostat, in 2021, renewable energy sources accounted for 37.5% of the EU's gross electricity consumption [36]. This indicates substantial progress towards the renewable energy targets set by the EU. The primary sources of renewable electricity in the EU include wind power and hydropower, with solar being the fastest-growing energy sources in the past years. In 2022, Hydro and nuclear sources made up for 32.04% of electricity generation, while wind and solar made up for 22.28%. The share of electricity from gas and coal is approximately the 36%.

Figure 4 shows the total electricity generation by source in Europe, highlighting a significant increase of wind and solar electricity over the last years. Wind power has experienced remarkable growth in the EU27 countries reaching a share of electricity generated from renewable sources of 37.5%. Offshore wind farms have emerged as a significant contributor to renewable electricity generation. According to the European Wind Energy Association, the cumulative installed capacity of offshore wind in the EU will reach 25.1 GW by the end of 2020 [30]. The development of offshore wind projects has been driven by technological advancements, cost reductions, and supportive policies. Hydropower remains a significant contributor to renewable electricity generation in some EU27 countries with a share of electricity generated from renewable sources of 32.1%. It provides a reliable and dispatchable source of renewable energy. Biomass is another important renewable energy source, utilized for both electricity and heat production,

particularly in regions with abundant biomass resources. Solar PV has witnessed the fastest progress in the EU27 over the past 15 years reaching a share of electricity generated from renewable sources of 15.1%. The decreasing costs of solar panels and favorable policy frameworks have contributed to the increased deployment of solar PV installations. In 2020, the EU27 added around 18.2 GW of new solar PV capacity, bringing the total installed capacity to over 137 GW [29].

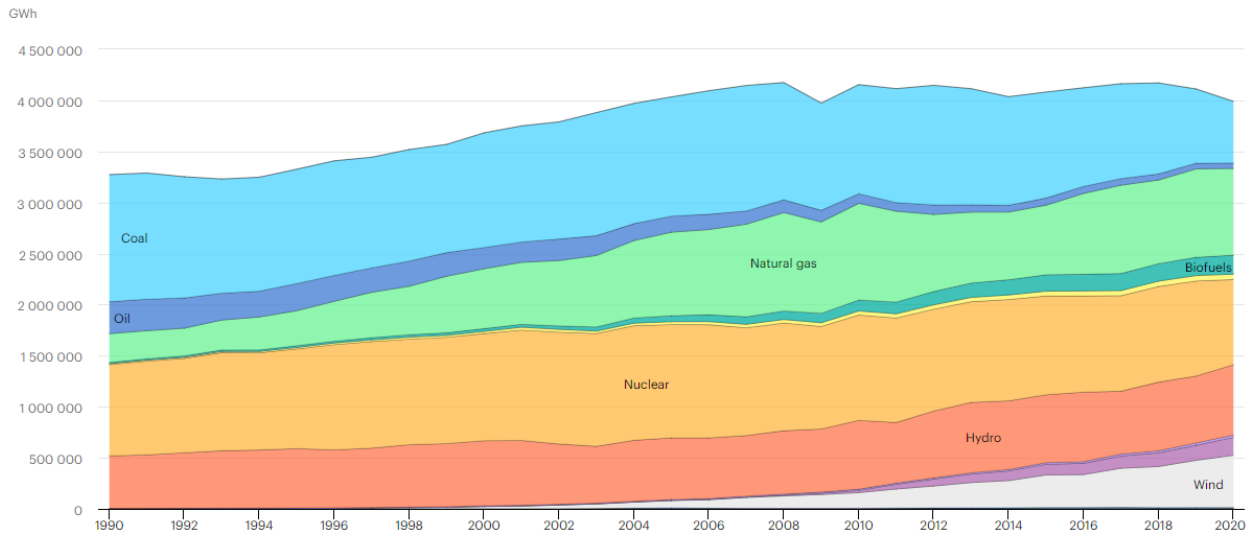


Figure 4 Total electricity generation by source, Europe 1990-2021 [38]

The shares of these renewable energy technologies vary across European countries based on factors such as resource availability, geographic location, and policy frameworks. For instance, Germany and Denmark have made significant investments in wind power, while Spain and Italy have capitalized on their solar potential. Hydropower-rich countries like Norway and Switzerland utilize their abundant water resources. These renewable energy technologies bring numerous advantages, including reduced greenhouse gas emissions, enhanced energy security, and job creation opportunities. However, they also face certain challenges. Wind and solar power are intermittent sources, dependent on weather conditions, necessitating grid integration strategies, and energy storage systems. Hydropower faces environmental concerns and requires suitable water resources. Biomass raises questions about sustainability and land use competition, while geothermal energy is constrained by geological limitations.

2.1.2. Austria

Electricity consumption of Austria in 2021 was 75.1 TWh. The change of annual electricity consumption of the country over the years is shown in Figure 5 below. The electricity sector in Austria has witnessed notable developments in recent years, particularly in the context of renewable electricity generation and decarbonization efforts. Austria has been actively pursuing a transition towards a more sustainable and low-carbon energy system, with a strong focus on renewable energy sources. In the last year, renewable energy sources covered 36.4% [37] of the total final consumption and 76.2% [37] in total electricity generation.

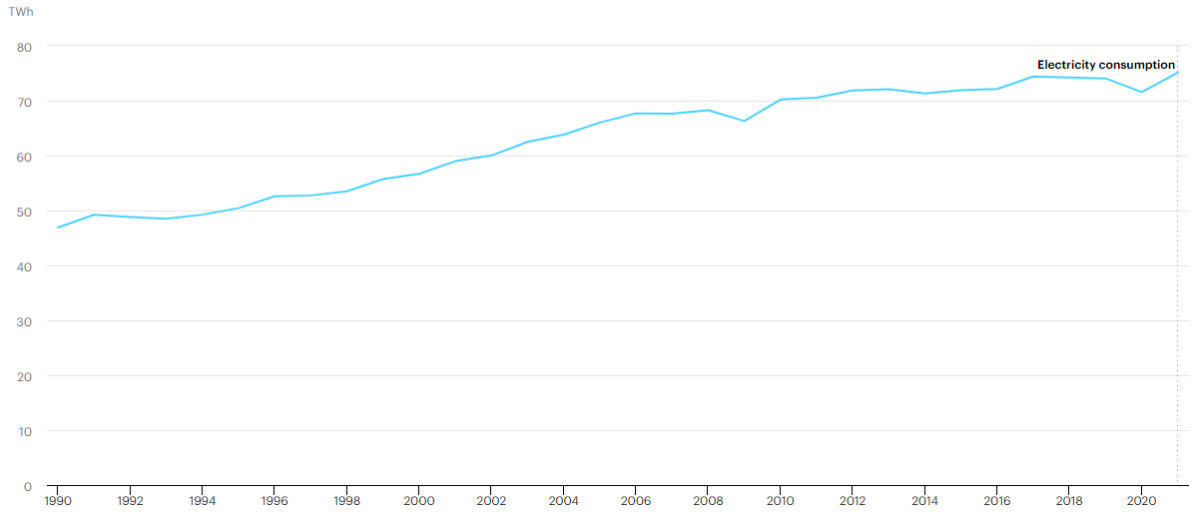


Figure 5 Electricity consumption of Austria between 1990-2021 [38]

Renewable electricity generation has played a significant role in Austria's energy landscape; the total electricity generation by source can be seen in Figure 6. The country has a long-standing tradition of harnessing its abundant hydropower resources, which continue to be the dominant renewable energy source, as it can be seen in Figure 6. In 2021, hydropower generated 42.5 terawatt hours (TWh), representing 66.91% of total electricity generation. Precipitation levels and other weather conditions affect annual hydropower generation, but the long-term trend in hydro generation has been stable; in the last two decades, the average hydropower generation was 39 TWh per year [27]. The extensive use of hydropower provides Austria with a stable and reliable electricity supply while contributing to decarbonization goals.

Furthermore, Austria has been making progress in the deployment of wind power which is becoming a key of success in reaching the target of electricity generation imposed by Austria's government. The country has witnessed a steady increase in wind energy installations, both onshore and offshore. Since 2010, wind generation has more than tripled reaching in 2021 a share of 10% of total electricity generation. PV generation is also increasing rapidly and in 2021 it accounted for 4% of total electricity generation. Residential rooftop systems provide 95% of PV generation. Austria is among the top five countries globally in terms of residential PV capacity per capita [27].

Biomass has also played a significant role in Austria's renewable electricity generation reaching a share of 2.2% of electricity generation in 2021. Derived from agricultural and forestry residues, biomass power plants contribute to renewable heat and electricity production, particularly in rural areas. The utilization of biomass helps reduce reliance on fossil fuels for heating and electricity, further supporting the decarbonization of the electricity sector. Electricity generation share by each resource from 1990 to 2022 is shown in Figure 6 below.

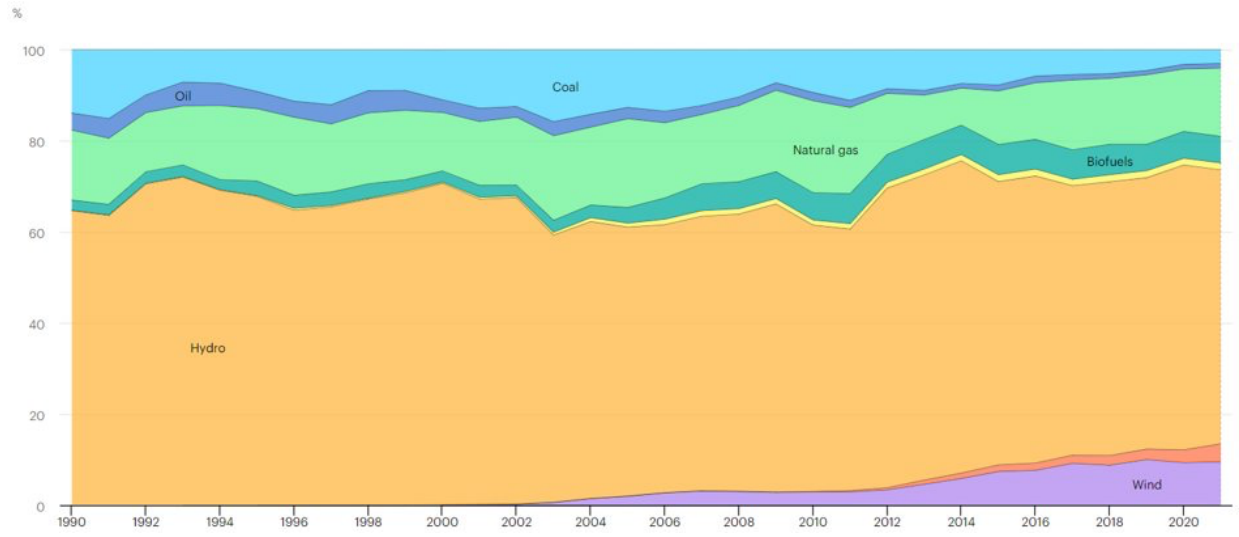


Figure 6 Total electricity generation by source, Austria 1990-2021 [38]

The shares of these renewable energy technologies vary in Austria based on their respective potentials and resource availability. Hydropower has traditionally been the dominant renewable energy source in Austria, contributing to the stability and reliability of the electricity grid. Wind power and solar PV are gaining momentum, driven by supportive policies and technological advancements.

2.1.3. Czech Republic

Electricity consumption of Czech Republic in 2021 was 69.7 TWh. The change of annual electricity consumption of the country over the years is shown in Figure 7 below. Even though, The Czech Republic has made notable progress in the electricity sector with a growing emphasis on renewable electricity generation and decarbonization efforts, the country is still highly dependent to coal and nuclear in electricity generation. The country has been actively transitioning towards a more sustainable and low-carbon energy system, aiming to reduce greenhouse gas emissions and increase the share of renewable energy sources in the electricity mix to achieve the EU goals. In 2021 the share of renewable energy resulted to be 17.76% [37], while the share of gross electricity consumption resulted to be 14.5% [36]; the total electricity generation by the different sources is shown in Figure 8. The primary sources of renewable electricity in the Czech Republic include wind power, solar photovoltaics (PV), biomass, and hydropower.

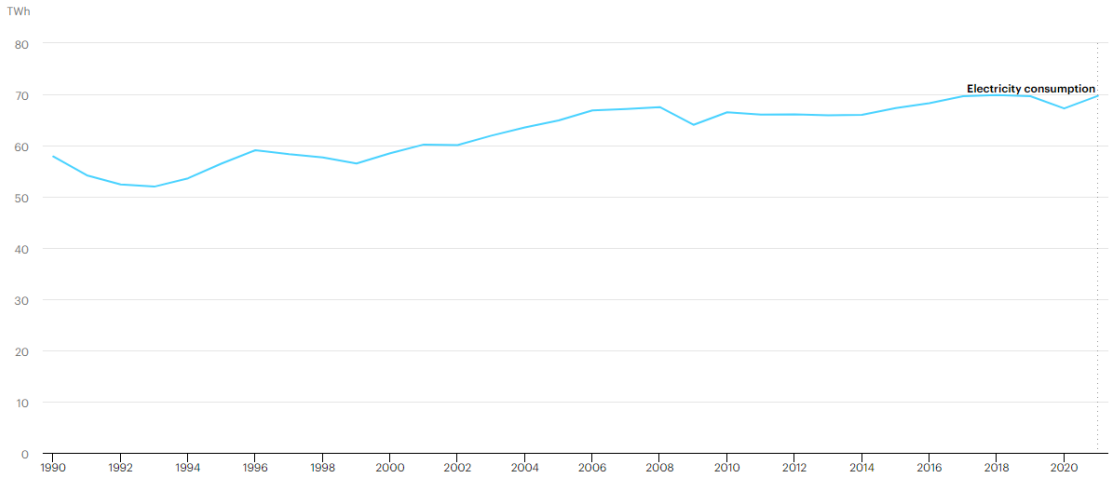


Figure 7 Electricity consumption of Czech Republic between 1990-2021 [38]

Wind power has experienced substantial development in the Czech Republic. The country has seen the installation of several wind farms, particularly in regions with favorable wind resources. The total installed wind power capacity reached 494 MW by the end of 2020, representing a significant increase compared to previous years [34] and is now accounting for 0.8% share in the electricity generation in 2022. Solar PV installations have also shown remarkable growth in the Czech Republic. Falling costs of solar panels, supportive policies, and favorable feed-in tariffs have contributed to the expansion of solar PV capacity, especially for households' rooftops. By the end of 2020, the cumulative installed solar PV capacity in the Czech Republic exceeded 2,900 MW [34] and in 2022 solar energy made up for 5.4% of the total electricity generation. Biomass also holds a crucial position in the Czech Republic's renewable electricity generation with a share of 2.8% in total electricity generation in 2022. The utilization of biomass-fired power plants not only contributes to renewable energy generation but also aids in the effective utilization of waste materials, thereby bolstering the country's decarbonization targets. Hydropower is another renewable energy source in the Czech Republic and it accounted for a 3.4% share of the total electricity produced in 2022. Small and medium-sized hydropower plants are widely distributed across the country and contribute to renewable electricity generation. While hydropower capacity has remained relatively stable, the focus has shifted toward the development of other renewable energy sources [36].

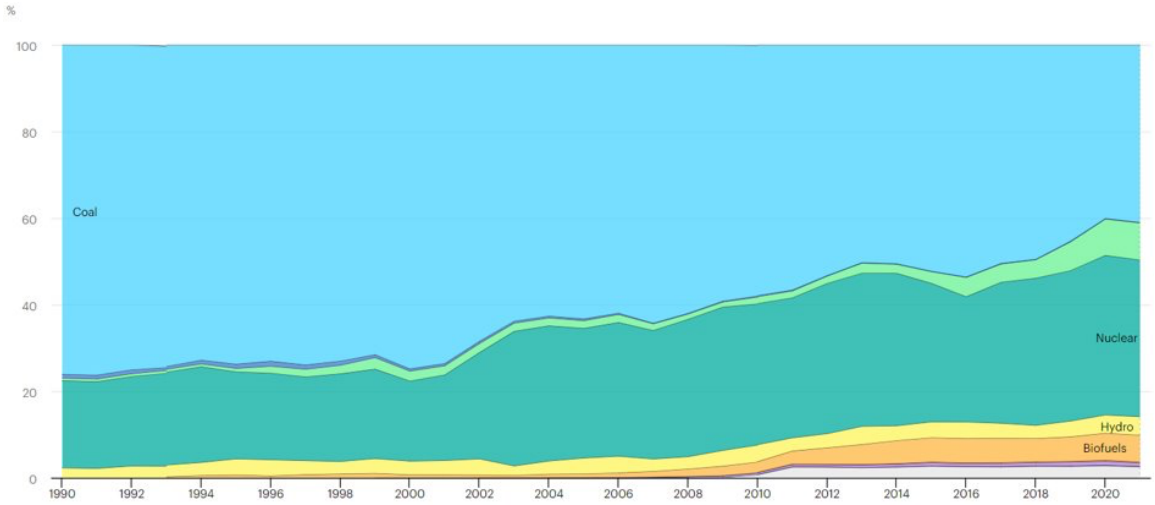


Figure 8 Total electricity generation by source, Czech Republic 1990-2021 [38]

While wind power is still in the early stages of development in the country, solar PV installations have experienced significant growth due to declining costs and supportive policies. Biomass utilization, including solid biomass and biogas, is widely employed for both electricity generation and heating purposes. Hydropower, as a long-standing renewable energy source, holds a substantial share of the country's electricity production. Geothermal energy is currently a minor contributor but has the potential for further development [36].

2.1.4. Comparison of Austria and the Czech Republic

Austria and the Czech Republic are two countries that have made significant progress in their respective electricity sectors, particularly in terms of renewable electricity generation and decarbonization efforts. While both countries share a commitment to transitioning towards sustainable energy systems, there are notable differences in their renewable energy profiles and technologies.

A comparison of the renewable electricity generation between the two countries reveals notable disparities in terms of the quantity of renewable electricity generated and the resources employed. Figure 9 illustrates the electricity generation data for Austria in 2021, highlighting the production of 42,540 GWh from hydro, 2,809 GWh from solar PV, and 6,740 GWh from wind sources.

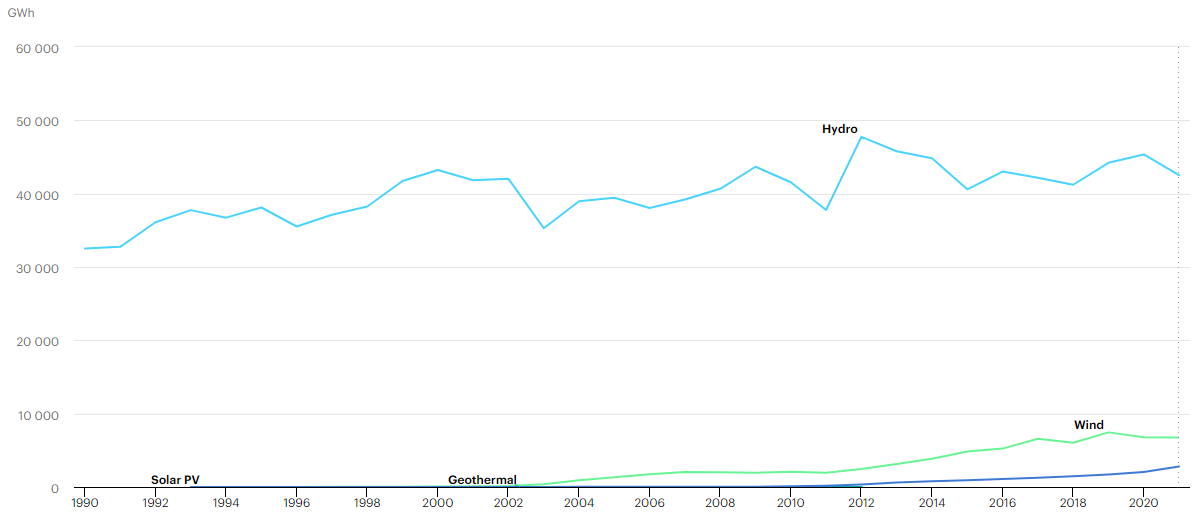


Figure 9 Renewable electricity generation by source, Austria 1990-2021 [38]

Furthermore, as depicted in Figure 10 below, the Czech Republic generated 3,620 GWh of electricity from hydro sources, 2,153 GWh from solar PV, and 602 GWh from wind power in 2021.

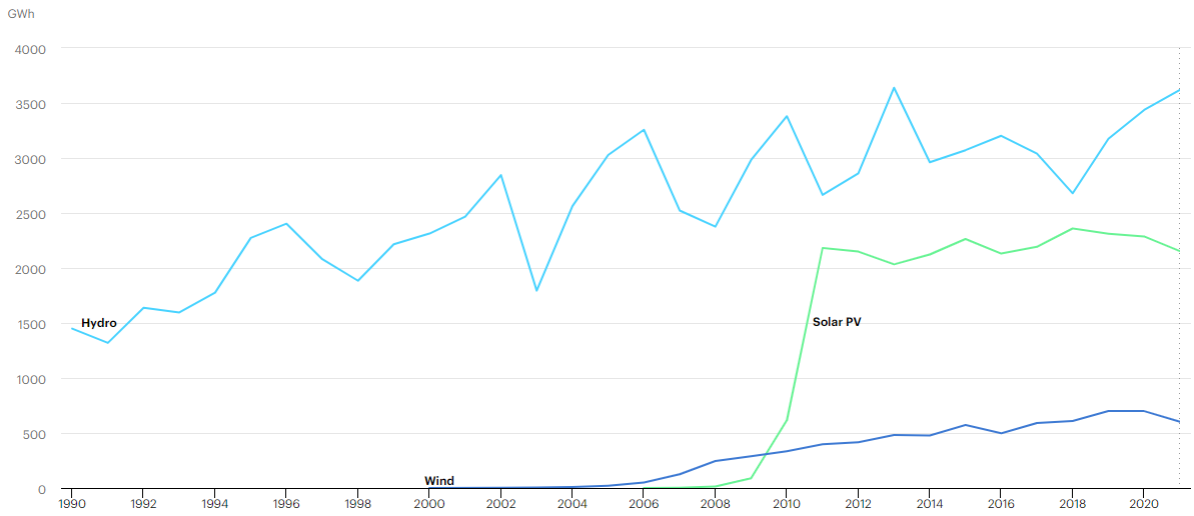


Figure 10 Renewable electricity generation by source, Czech Republic 1990-2021 [38]

Despite the comparable total electricity consumption observed in both countries during 2021, significant disparities emerge regarding the proportion of renewable electricity generated. Within the Czech Republic, coal and nuclear energy sources persist as the predominant contributors to electricity generation, while Austria relies predominantly on hydroelectric power. This disparity underscores the divergent approaches and priorities adopted by these nations in their respective energy landscapes. This comparison is illustrated in Figure 11 below.

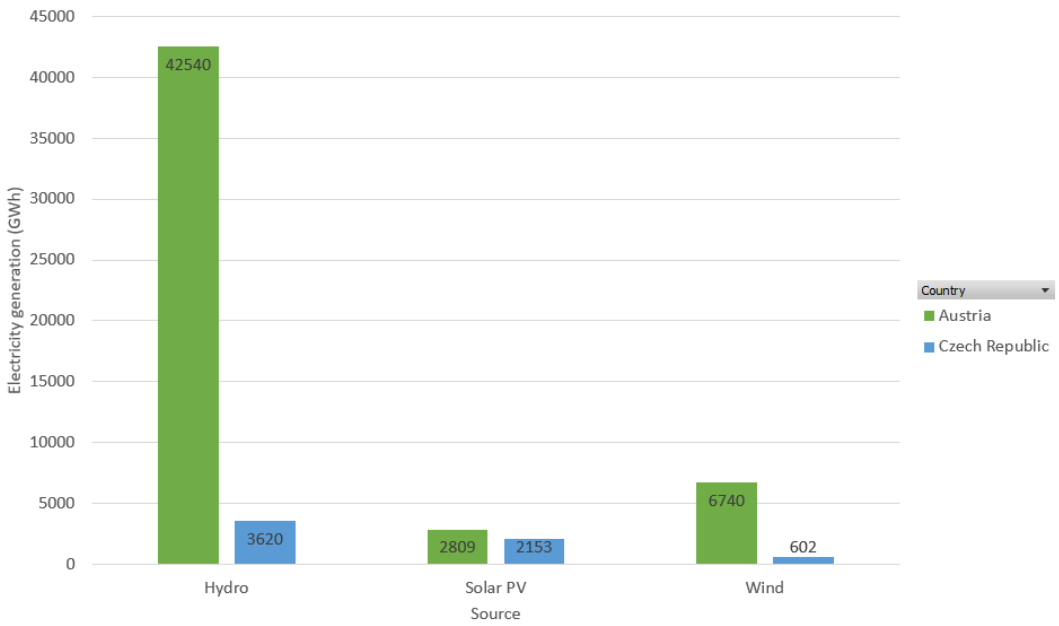


Figure 11 comparison of renewable electricity generation in 2021 between Austria and Czech Republic (source: data from IEA - https://www.iea.org)

The Czech Republic continues to heavily rely on coal and nuclear power for electricity generation, which hinders the growth of renewable energy sources. Coal, contributes to greenhouse gas emissions and is detrimental to efforts aimed at mitigating climate change. Nuclear power, on the other hand, has its own

set of challenges, including concerns related to safety and waste disposal. These factors limit the integration of renewable energy sources and hinder the progress towards a sustainable energy system. In contrast, Austria has strategically prioritized the development of hydroelectric power as a key driver of its renewable energy portfolio. The country's geographic advantage, with its abundant rivers and water resources, enables the substantial generation of electricity from hydro sources. By harnessing the power of flowing water, Austria has capitalized on its hydroelectric potential, thus positioning itself as a frontrunner in the promotion of renewable electricity generation.

The differing energy profiles of these countries highlight the importance of policy frameworks, government support, and long-term planning in shaping the energy mix and transitioning towards sustainable energy systems. The Czech Republic faces the challenge of reducing its reliance on coal and nuclear power while simultaneously promoting the deployment of renewable energy technologies with a focus on wind power and solar PV development due to favorable conditions and advancements in these technologies. In contrast, Austria's emphasis on hydroelectric power showcases the significance of capitalizing on local renewable resources and adopting appropriate technologies to achieve a greener energy landscape.

It is evident that fostering the growth of renewable electricity generation requires comprehensive strategies, supportive policies, and a commitment to transitioning away from carbon-intensive and non-renewable energy sources. By diversifying their energy mix and placing greater emphasis on renewable sources such as hydroelectric power, countries can significantly contribute to global efforts to mitigate climate change, reduce greenhouse gas emissions, and establish sustainable energy systems.

2.2. Targets

2.2.1. EU Targets

The UE released the Renewable Energy Directive in 2009 as a legal framework for the development of renewable energy across all sectors of the EU economy. Thanks to this directive, the share of renewable energy sources in energy consumption has increased from 12.5% in 2010 to 21.8% in 2021 [21]. Given the need to speed up the EU clean energy transition, the Directive was revised with new targets and strategies, and it entered into force in 2018. The revision established a new binding renewable energy target for the EU for 2030 of at least 32%, with a clause for a possible upwards revision by 2023; in fact, to meet the higher climate ambition, as presented in the European Green Deal in December 2019, further revisions of the directive were needed. The Commission presented Europe’s new 2030 climate targets, including a proposal for amending the Renewable Energy Directive, on 14 July 2021; it seeks to increase the current target to at least 40% renewable energy sources in the EU’s overall energy mix by 2030 [21]. On 18 May 2022, the Commission published the REPowerEU plan, which sets out a series of measures to rapidly reduce the EU’s dependence on Russian fossil fuels well before 2030 by accelerating the clean energy transition [19]. As part of its scaling up of renewable energy in power generation, industry, buildings, and transport, the Commission proposed to increase the target in the directive to 45% by 2030. On 30 March 2023, the European Parliament and the Council reached a provisional agreement to raise the binding renewable energy target to at least 42.5% by 2030 [21].

While progress has been made, challenges remain in achieving the EU's renewable energy targets. These challenges include grid integration of intermittent renewable energy sources, variability of renewable energy production, regulatory barriers, and financing constraints. However, continuous efforts are being made to address these challenges through technological advancements, market reforms, and policy improvements. In conclusion, the EU27 countries are making significant strides in renewable electricity generation and decarbonization of their electricity sectors. The targets set by the EU, along with

supportive policies and advancements in renewable energy technologies, have contributed to the growth of wind power, solar PV, hydropower, and biomass. Despite challenges, the EU27 countries are committed to a sustainable energy future and continue to work towards achieving their renewable energy goals.

2.2.2. Austria Targets

To drive the transition towards a sustainable energy future, Austria has set ambitious targets. The Austrian Energy and Climate Plan (NEKP) aims to achieve a 100% renewable electricity supply by 2030 and 46-50% gross energy consumption [27]. This commitment demonstrates Austria's strong dedication to decarbonize its electricity sector and significantly reduce greenhouse gas emissions. The new government program adopted in January 2020 calls for Austria to reach climate neutrality by 2040, which will require a significant increase in the pace of renewable deployment. In Table 1, the targets fixed in 2018 for 2020 and 2030 are shown in detail. Achieving the 100% renewable electricity generation target will require new investments in generation capacity, repowering of older wind turbines, and additional grid infrastructure, while slow permitting procedures remain a challenge. As wind and solar power continue to increase, integration of variable renewable energy will become more important, and Austria will benefit from the flexibility offered by its hydropower. Austria's commitment to these EU initiatives ensures a collaborative approach toward achieving a sustainable and low-carbon energy transition.

Table 1 Austrian national targets [27]

Renewable share by sector (% of gross final consumption)	Status 2018	Targets	
		2020	2030
Gross final consumption	33.4%	34%	46-50%
Transport	9.8%	10%	14%
Electricity	73.1%	No target	100%*

2.2.3. Czech Republic Targets

The Czech Republic's renewable energy targets are mainly driven by obligations under the European Union's Renewable Energy Directive through the National Energy and Climate Plan (NECP) for the period to 2030 [26]. For 2030, the Czech Republic is committed to increasing the share of renewables in gross final consumption to 22% as part of its contribution to the previous EU-wide target of 32% [26]. The government has set an ambition to reach 17% of renewables in total electricity generation by 2030 [26]. In Table 2 the targets fixed in 2019 for 2020 and 2030 are provided. These targets demonstrate the country's commitment to renewable energy deployment and decarbonization of the electricity sector.

Table 2 Czech Republic's national targets [26]

Renewable share by sector (% of gross final consumption)	Targets		
	2019	**2020**	**2030**
Gross final consumption	16.2%	13%	22%
Transport	7.8%	10.8%	14%
Electricity	14.1%	13.5%	17%
Heating and cooling	22.7%	15.5%	1 percentage point annually to 2030

2.3. Strategies and supporting schemes

Several strategies are being promoted in the EU including cooperation mechanisms, policy frameworks and support schemes.

Support schemes remain the most important way to increase the share of electricity from renewable energy sources at a national level. A support scheme is defined as 'any instrument, scheme or mechanism applied by a Member State, or a group of Member States, that promotes the use of energy from renewable sources by reducing the cost of that energy, increasing the price at which it can be sold, or increasing, by means of a renewable energy obligation or otherwise, the volume of such energy purchased' [18]. All these incentives mechanisms can be divided into four groups: investment supports, generation supports, quantity targets and carbon policies [2].

Investment supports play a crucial role in the development of renewable energy technologies as they require large amounts of money, and they cover financial supports such as subsidies, loans, grants and tax incentives. Grants and subsidies are a type of financial support provided by governments or other organizations to renewable energy projects; they can be used to cover a variety of costs, such as project development, equipment purchase, and construction. Tax incentives include supports such as low-interest and long-term credit, environmental tax exemption and value-added tax exemption [2]. R&D fundings can be also considered as they improve existing renewable energy technologies by establishing R&D facilities or developing novel technologies; R&D projects come with a high level of risk and uncertainty, making government support essential.

Generation support includes Feed-in Tariffs (FIT), Feed-in Premium (FIP), net-metering and tendering and auctions schemes [2]. FIT is historically one of the main mechanisms used in the UE and it guarantees renewable energy producers a fixed price for the electricity that they generate to assure stable and predictable revenues streams. In other words, the FIT mechanism is the obligation to purchase electricity by the public with a predetermined fixed price. Moreover, FIT plays a crucial role as one of the most common forms of grid connection incentive. FIP is an additional support payment above the electricity market price providing an extra revenue stream; if the premium is set at the 'right' level (theoretically at a level equal to the external costs of conventional power), it allows renewables to compete with conventional sources [1]. Both these mechanisms make energy projects more profitable and reduce income risks in order to encourage investors. Tendering and auctions schemes are competitive mechanisms to allocate financial support to renewable energy projects; they are designed to ensure a transparent and competitive process for selecting renewable energy projects promoting a cost-effective deployment of renewable energy. Furthermore, the use of auctions to grant aid for electricity generation from renewable energy sources can stimulate competition among potential beneficiaries, avoid the risk

of overcompensation and more generally can lead to the minimization of support costs [24]. Net-metering allows renewable energy system owners to sell excess electricity generated back to the grid, providing a financial incentive for investment in small-scale renewable energy projects [2].

Quantity targets are ensured through the quota obligation (QO) which consists of a specific renewable energy target (certain quantity or percentage of electricity to be guaranteed from renewable energy sources) defined by the government. According to this target, the generators, wholesalers, retailers or consumers are obligated to supply a certain percentage of electricity from renewable energy sources [4]. QO are usually combined with green energy certificates (TGC systems in Europe [1]) which are obtained by energy suppliers based on the energy they produce and are sent to regulatory authorities as proof of quota obligation fulfillment.

Carbon policies are regulations issued by governments to reduce industrial enterprises' carbon emissions. These policies support renewable electricity by making carbon energy sources more expensive, thus increasing the attractiveness of renewable energy sources; this is the reason why they can be defined as indirect support schemes.

2.3.1. Strategies in the EU

The implementation of various support mechanisms is promoted by the revised Renewable Energy Directive (RED) of 2018. The primary objective of the RED is to establish an energy framework that fosters the expansion of renewable energy sources, to achieve a renewable energy share of up to 32% by 2030. Within the European Union (EU), individual member states possess the freedom to adopt their suite of incentives and measures to promote the generation of electricity from renewable energy sources, provided that they align with the objectives and principles outlined in the RED. Figure 12 presented below illustrates a selection of the most prevalent support mechanisms utilized in this context. It is possible to notice a high prevalence of feed-in tariffs (FIT) and feed-in premiums (FIP) which are often combined together or with investment supports such as investment grants. Countries highlighted in red and orange decided to adopt green certificates to ensure effective quota obligations.

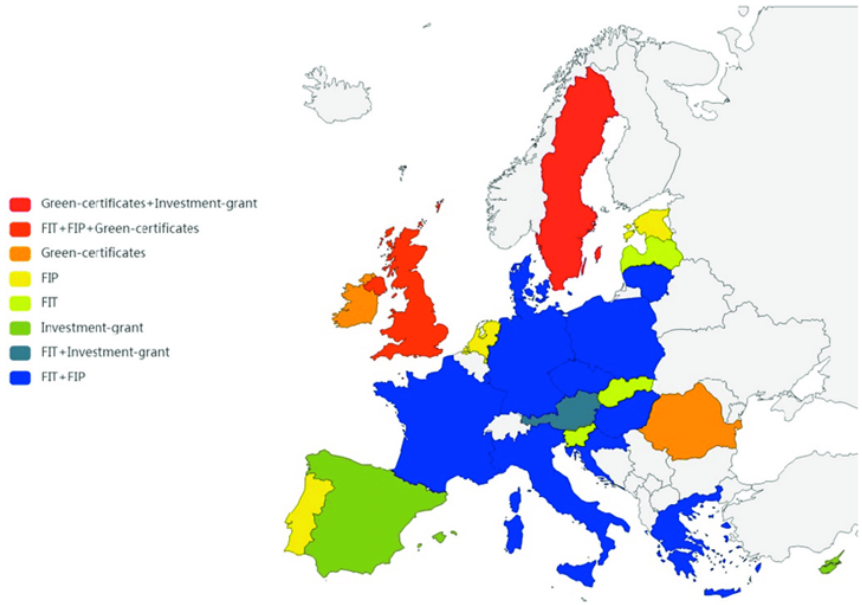


Figure 12 Main supports schemes for renewable electricity in the EU [17]

FIT support has been the most popular for a long time by being effective at relatively low additional costs for final customers. A well-designed FIT system provides a certain deployment of renewable electricity in the shortest time and at lowest costs for society [1]. It is preferable to national green certificate trading schemes as it is easy to implement, it can be revised to account for new capacities in a very short time, the administration costs are usually lower [1] and it minimizes the total transfer costs [4]. At the same time FIT can bring governments a financial burden over the long term [2] and does not reflect actual market conditions [24]; this is why EU countries are preferring nowadays premium-support schemes. To alleviate the burdens associated with FIT, quota obligations and green energy certificates can be employed, but they may also diminish participants' profits [2]. Carbon policies, such as carbon pricing, are generally not the most effective means to promote renewable energy; financial support mechanisms should be integrated with such policies. It is worth noting that excessively high carbon taxes may impact manufacturers' business performance and industry development [2]. In recent years, many countries have increased the number of market-oriented mechanisms, such as tendering and auctions schemes, in order to achieve cost-effective renewable energy deployment over the long term [16]. Across the EU, operational supports, such as certificate schemes, tariffs or premiums, are more widely applied, allocated in the case of utility-scale projects most often on a market basis through competitive tenders [24]. Most EU member states have implemented tender-based renewable electricity support schemes, underscoring the increasing importance of optimal bidding strategies [2]. There are only a few exceptions: countries such as Austria and the Czech Republic [24], where only recently plans for the implementation of tender based renewable support and the organization of first auction is being introduced. Currently, most countries in Europe operate premium-based support schemes through tenders which are market-based instruments for determining level and awardees of RES support [24].

The Renewable Energy Directive (RED) also fosters cooperation mechanisms among EU countries to exploit renewable resources and achieve their national renewable energy targets. Three cooperation mechanisms are employed: statistical transfers, joint projects between EU countries or with third countries, and joint support schemes [18]. Statistical transfers involve deducting a certain amount of renewable energy from one country's progress toward its target and allocating it to another country. This cooperation mechanism incentivizes EU countries to exceed their targets by providing payments for transferred energy. In December 2021, the Union Renewables Development Platform was launched by the Commission to facilitate statistical transfers of renewable energy among EU countries [21]. Joint projects allow two or more EU countries to co-fund renewable energy projects in electricity or heating and cooling, enabling the sharing of resulting renewable energy to meet their targets [21]. Similarly, joint support schemes involve co-funding schemes to stimulate renewable energy production in one or both territories, encompassing measures such as a common feed-in tariff, feed-in premium, or quota [21].

Apart from the RED and support schemes, the EU promotes additional strategies. The REPowerEU plan encompasses all EU member states and focuses on rapidly reducing dependence on Russian fossil fuels by expediting the clean energy transition. This plan rests on three pillars: energy conservation, clean energy production, and diversification of the EU's energy supplies [19]. Significant emphasis is also placed on the need to repower renewable energy power plants and streamline permit-granting processes. Currently, obtaining permits for wind projects can take up to nine years, while ground-mounted solar projects can take up to 4.5 years [19]. Guarantees of Origin (GOs) serve as instruments to verify the origin of electricity generated from renewable energy sources. Member states employ GOs to ensure transparency, objectivity, and non-discrimination in guaranteeing the origin of renewable electricity [28].

2.3.2. Strategies in Austria

In Austria, the support for electricity derived from renewable sources primarily relied on a technology-dependent feed-in tariff (FIT) and investment subsidies. The FIT provided financial incentives for wind, solid and liquid biomass, biogas, and geothermal energy, irrespective of the system capacity measured in megawatts (MW). However, the FIT for photovoltaic (PV) systems was restricted to capacities exceeding 5 kilowatts (kW), whereas for hydropower, it only applied to systems with capacities below 2 MW. Furthermore, the FIT encompassed additional technology-specific requirements pertaining to system efficiency, fuel stock types, and technical specifications. The Minister for Climate Action, Environment, Energy, Mobility, Innovation, and Technology (BMK) adjusted the level of the feed-in tariff annually for each technology [27].

To aid in achieving the target of 100% electricity generation from renewable energy sources, the Austria National's Recovery and Resilience Plan received approval from the European Commission in July 2021. As part of this plan, Austria is replacing the aforementioned support scheme with a novel system based on market premiums and competitive allocation of aid. The aid will be granted in the form of a top-up premium, which will be calculated as the discrepancy between the average production cost for each renewable technology and the prevailing electricity market price. Specifically, wind, solar energy, and biomass electricity will be eligible for aid through technology-specific competitive bidding processes, aimed at maintaining support at a proportionate and cost-effective level. Austria has also incorporated mixed-technology tenders, encompassing wind and hydro technologies, within their framework [25]. The Federal Act on the Expansion of Energy from Renewable Sources, enacted in July 2021, addresses the support schemes, particularly the FIP and investment grants, for electricity derived from renewable sources, along with the corresponding eligibility requirements. Auctions are held to determine the awardees of feed-in premiums for solar PV, biomass and wind power plants (for the latter as of 2023) and the guaranteed price used to calculate the feed-in-premiums [20], while the investment grants are awarded through subsidy calls with a limited time frame for applications.

Tax incentives are available for renewable energy projects, and net metering is accessible for small-scale installations of renewable energy [10]. Although quota obligation has not been implemented at the national level, it is mandated by the EU renewable energy directive. Carbon policies encompass carbon pricing, involving taxation on fossil fuels such as heating oil, natural gas, and coal, to incentivize the utilization of low-carbon alternatives, alongside emission trading system, which establishes a limit on emissions from industrial sectors. Like the RED, the emission trading system and guarantees of origin are policies that encompass the entirety of the European Union.

2.3.3. Strategies in the Czech Republic

In the Czech Republic, support for renewable energy was provided through two mechanisms: a guaranteed feed-in tariff or a fixed premium tariff known as the green bonus, which is paid in addition to the market price. Plant operators have the freedom to choose between these two options [10]. The Czech Energy Regulatory Office established the feed-in tariff and green bonuses on an annual basis. The feed-in tariff was guaranteed for a period of 15 years with a 2% annual increase, except for installations using biogas, biomass, and bioliquid. The level of the feed-in tariff was determined based on the year of installation operation. The obligated off-taker was obliged to pay the difference between the guaranteed purchase price and the hourly market price of electricity to the electricity market operator [26]. Under the green bonus scheme, renewable electricity producers receive the market price from the off-taker, and the market operator pays the green bonus, which is linked to the feed-in tariff of a comparable generation source. The green bonus scheme offers several advantages compared to the guaranteed purchase price scheme. Producers have the flexibility to sell their electricity output to any customer or electricity trader

at the market price while receiving the green bonus as an additional payment. Alternatively, they can self-consume the generated electricity and still receive the green bonus [26].

Operators of hydropower plants with a capacity of less than 10 MW may receive subsidies under the operational program "Entrepreneurship and Innovation for Competitiveness". The deployment of photovoltaic systems in public buildings is incentivized by the operational program "Environment". Moreover, renewable energy plants are exempt from real estate tax [10]. Operators of renewable energy plants are entitled to priority connection to the grid, and the use and expansion of the grid are regulated by general energy legislation. An amendment to the Energy Act in 2015 eliminated the requirement for an electricity generation license for small generating sources up to 10 kilowatts (kW) primarily intended for self-consumption, even if they are connected to the transmission or distribution system. The distribution system operator cannot refuse to connect these small plants [26]. Tax incentives are promoted by exempting operators of renewable energy sources generating electricity from real estate tax. The Czech Republic government has adopted Green Certificates, and the Emission Trading System is utilized as a carbon policy.

With the amendment to Act No. 165/2012 on incentivized energy sources, passed in September 2021, the Ministry of Industry and Trade will be able to resume auctions to provide support to renewable energy power plants. The amendment proposed abandoning the feed-in tariff and retaining only hourly green bonuses for renewable energy sources with an installed capacity of less than 1 MW. For sources exceeding 1 MW (6 MW for wind sources), the proposed Draft RES Amendment suggests implementing an auction system where the bidder offering the lowest subsidy for the agreed-upon capacity will be granted the subsidy. Additionally, the amendment includes a crucial provision for reviewing the funding of power plants, especially those commissioned between 2006 and 2010, to ensure they are not overfunded. This allows the Czech Republic government to reduce incentives in overfunded sectors to ensure that the internal rate of return (IRR) remains within the desired range throughout the funding period [22]. The amendment to the Energy Law, effective since January 2023, aims to further expand the deployment of renewable energy by allowing the construction of installations up to 50 kWp without requiring a license or building permit (previously limited to 10 kWp). Moreover, the amendment acknowledges the public interest in operating renewable energy installations with an installed capacity exceeding 1 MWp [23].

3. Conclusion and outlook

The promotion of renewable electricity generation is essential for combating climate change and achieving sustainable and low-carbon energy systems. Its role is crucial for contributing to the diversification of the energy mix so as to mitigate the risks associated with energy price fluctuations and supply disruptions and to reduce vulnerability to geopolitical tensions and external shocks. Furthermore, an increasing deployment of renewable electricity helps to reduce greenhouse gas emissions and, therefore, to mitigate the climate change. Many barriers still need to be overcome and efforts are being made to address renewable resources constraints, grid integration and efficient energy storage solutions.

This research paper examined the targets, strategies, and technologies employed in the European Union (EU), Austria, and the Czech Republic to promote renewable electricity.

The EU has demonstrated a commitment to renewable energy by creating policy frameworks such as the Renewable Energy Directive and REPowerEU plan. Targets are provided to increase the share of renewable energy in the final energy consumption, driving the deployment of diverse renewable technologies. The EU's technology-neutral approach allows member states to choose the most suitable support schemes and renewable energy sources based on their specific circumstances. Across Europe, various renewable energy technologies are contributing to the decarbonization efforts. Wind and hydro

power are responsible of the largest share of electricity generation from renewable sources, while solar power is resulting to be a key energy source due to its fast growth. Each technology has its advantages and challenges, such as intermittency, environmental concerns, and resource limitations. However, advancements in technology, supportive policies, and ongoing research and development efforts are addressing these challenges and driving the adoption of renewable energy. The EU is promoting several strategies such as cooperation mechanisms, emission trading systems, guarantees of origin and supporting schemes. The EU scenario and the analysis of Austria and Czech Republic have shown that feed-in tariff is acquiring less popularity than before since it can bring financial burdens to governments over the long terms, and it doesn't reflect actual market conditions. Currently, most countries in Europe operate premium-based support schemes through tenders and auctions which are market-based instruments for determining level and awardees of RES support. Auctions are designed to ensure a transparent and competitive process for selecting renewable energy projects promoting a cost-effective deployment of renewable energy; they can stimulate competition among potential beneficiaries, avoid the risk of overcompensation and lead to the minimization of support costs.

Austria has made significant progress in promoting renewable electricity through its supportive regulatory framework and the development of key technologies like wind, hydro and solar. Renewable energy sources covered 36.4% of the total final consumption and 76.2% in total electricity generation. Although wind and solar are rapidly increasing in the share of gross electricity generation, hydro remain the dominant source due to the country's geographic advantage, with its abundant rivers and water resources and it represents 66,91% of the total electricity generation. The country has set the ambitious target of achieving 100% electricity generation from renewable sources by 2030. Austria has employed for a long time a technology-dependent feed-in tariff system, which provides financial incentives for various renewable energy technologies. The recent transition to a novel system based on market premiums, investment grants and competitive allocation of aid demonstrates Austria's commitment to cost-effective and proportionate support for renewable energy over the long terms.

The Czech Republic has also embraced renewable electricity generation, with a focus on solar photovoltaic (PV) systems through a strong promotion of PV households' rooftop, biomass and hydropower. In 2021 the share of renewable energy resulted to be 17.76%, while the share of gross electricity consumption resulted to be 14.5%. Wind is also rapidly increasing for what regard electricity generation in the last years. The country is making efforts to promote a renewable energy transition and has set a target of achieving 17% of total electricity generation. The country offers operators the choice between a guaranteed feed-in tariff and a fixed premium tariff known as the green bonus. The recent amendment to the Energy Law introduces an auction system for the allocation of aid to renewable energy sources and aims to reduce the usage of FIT. With this amendment Czech Republic is planning to reduce supports to overfunded sectors by focusing on investment subsidies allocated through tendering and auctions schemes. Nevertheless, it is crucial to acknowledge that the Czech Republic is faced with significant challenges on its path towards achieving a fully decarbonized electricity sector, primarily due to its reliance on coal and nuclear power, which remain the two main sources of electricity by far. These traditional energy sources pose obstacles to the country's ambitions of transitioning to a more sustainable and environmentally friendly energy system.

The discussions surrounding renewable electricity generation in Europe highlight the importance of a comprehensive and integrated approach. It involves a combination of regulatory frameworks, targets, financial incentives, grid integration strategies, energy storage solutions, and international collaborations. Collaboration between governments, industry stakeholders, and research institutions is vital for sharing best practices, accelerating innovation, and achieving renewable energy targets. The comparison between Austria and Czech Republic represents a good basis for future studies as it highlights two very different

situation, with the first country being one of the leaders in EU regarding renewable electricity generation and the second still struggling to shift from traditional energy resources to renewables. Despite these two different scenarios, both countries are making efforts to increase their targets by implementing similar support schemes with feed-in premium, subsidies and auctions schemes being significant for both. The fast pace in which supporting schemes, strategies and targets are changing over the last years require for the future a constant analysis of the situation in EU, Austria and Czech Republic. The technological current situation helps to understand which efforts have been made and how the countries intend to achieve their targets. Nevertheless, technological and administrative challenges remain an important issue to be constantly addressed; slow permit granting processes for renewable energy projects, energy storage solutions and grid integration are some of the main themes that need to be investigated in the future. Continues efforts in policy development, technological advancements, and international cooperation will further drive the adoption of renewable electricity and contribute to a cleaner and more sustainable energy landscape.

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