Energy Governance in Europe. A Comparative Analysis of Transition Pathways[1] [2]

Conference of the Research Section "Comparative Politics" of the German Political Science Association (Deutsche Vereinigung für Politikwissenschaft – DVPW), 22.-23.09.2022

Panel: Political Climate Change: Regional, European and Global Comparative Perspectives

Authors: Nils Bruch, Jörg Kemmerzell, Michèle Knodt (Institute of Political Science, Technical University Darmstadt)

[1] This work was funded by the Hessian Ministry of Higher Education, Research, Science and the Arts – Clean Circles cluster, and the Kopernikus project "Ariadne" (FKZ 03SFK5LO) by the German Federal Ministry of Education.

[2] Please note that Section 4 on explaining the different pathways is incomplete and only preliminary and needs further development. However, first ideas on how to operationalize the "independent variables" will be presented at the conference.

Abstract

At the latest with the war in Ukraine, energy policy, which is a hot topic in European politics anyway, moved to the center of political debates. It became clear that moving away from fossil fuel-based energy systems is not only related to reducing greenhouse gas emissions and mitigating climate change, but equally to energy security, energy affordability, and foreign policy strategies. However, national energy systems in Europe are very heterogeneous, as structural conditions like geographic circumstances, economic traditions, and critical policy decisions create distinct path-dependencies, that also shape current national and European energy policy discourses and transition pathways. To outline the distinct national pathways in a European context, we are examining data on the development of the European energy system and draw on examples from individual countries. We first assess the long-term evolution of Europe's energy mixes and then continue with a closer look at the developments of the main energy source for the decarbonization, renewable energy. To assess the overall results of the energy transition in Europe, we develop a scoring system that takes into account both transition successes and greenhouse gas reductions. This scoring system is then applied to the EU-27 and the UK to compare the results of the different countries and to take stock of the development over the last 20 years. The comparative analysis reveals a variety of transition configurations that will shape the future evolution of the European energy system. Mapping these variations is also important in light of current and emerging conflicts over European energy policy and in assessing medium- and long-term challenges on the path to climate neutrality by 2050.

1. Introduction

Energy transitions are nothing new in the development of humankind, as major transitions from the use of traditional biomass to coal and other fossil fuels as our primary energy sources can be observed in the past. The European energy systems as we know them today are heavily shaped by the *third energy transition.* According to the environmental historian Vaclav Smil, the first energy transition came with the ability to make a fire by burning plants. The invention of farming established the second transition, which converted solar energy into food resources and replaced the sustenance economy. The third transition came along with industrialization and the rise of fossil fuels, (coal, mineral oil, and natural gas), and energy supply became the domain of machines, such as coal-fired power plants (Smil 2015, 2021). However, industrialization took different national path developments, since energy systems depend on geographic conditions as well as on a country's particular economic development and crucial political decisions (e.g. to phase in or refrain from energy supply by nuclear power). These path developments constitute powerful legacies and inertia even for the course of the *fourth energy transition*, which unlike the first three, aspires to climb back down the power density ladder, from highly concentrated fossil fuels to more dispersed renewable sources (Smil 2015).

It comes as no surprise that this fourth energy transition while displaying more or less an overall trend, at least in Europe, took different path developments with various policy instruments resulting in a variety of governance regimes. Even European policies spur differentiation rather than unification, as a recent analysis of renewable energy policies, has shown (Boasson et al. 2021). Therefore, the current European energy and climate goals (climate-neutrality by 2050) and policies (such as the *National Energy and Climate Plans* or the *EU Taxonomy for Sustainable Activities*) will probably lead to diverging and sometimes competing answers when it comes to implementation by national governance.

In this study, we portray energy governance in Europe by examining statistical data on the development of the European energy system and drawing on examples from individual countries. We first assess the long-term evolution of Europe's energy mix and take a closer look at the renewable energy development as the heart of the energy transition, as well as governance structures and policy instruments. To assess the overall results of the energy transition in Europe, we develop a scoring system that takes into account both transition successes and greenhouse gas reductions. This scoring system is then applied to the EU-27 and the UK to compare the results of the different countries and to take stock of the development over the last 20 years. Finally, we give an outlook on the European challenges and perspectives on the way to climate neutrality by 2050.

2. Long-Term Development of the European Energy Mix

Looking at long-term developments of the European energy mix grants important insights into which achievements have been made by the energy policies of the European Union in the member states and how other political, economic and social developments influence the energy sector over time.

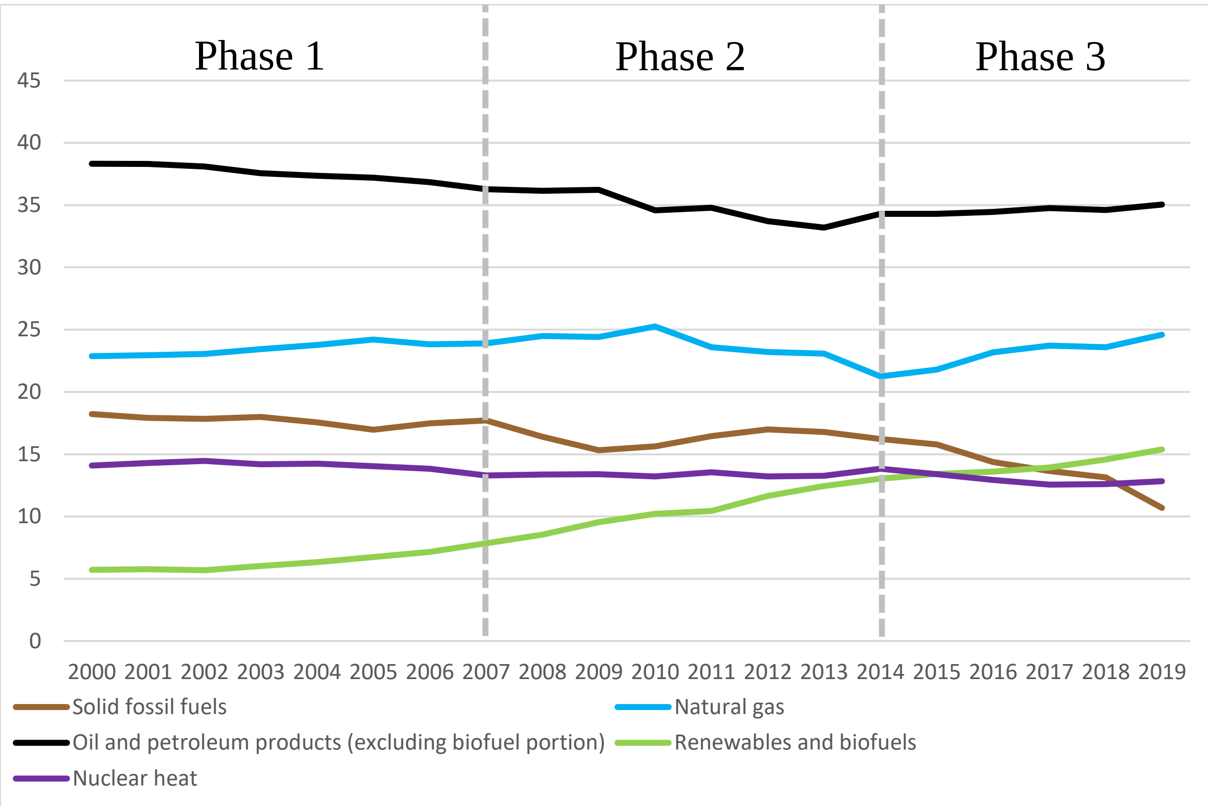

Figure 1: Long-Term Development of the Energy Mix in the European Union, Share of Gross Inland Consumption 2000-2019 (Eurostat 2021a)

Figure 1 shows the energy mix in the European Union from 2000 to 2019. This time frame can be separated into three phases to outline major developments that ultimately led to the present energy mix. The first phase (2000-2007) is characterized by a high consistency in the composition of the energy mix, with no disruptive changes and only minor fluctuations. Although the objective of a comprehensive European energy transition was already discussed, not enough political and societal momentum has built up yet to initiate developments that would have a significant influence on the total European energy mix. The immediate effects and aftermath of the global economic crisis, which started in 2008 and led to a worldwide recession, shape the second phase (2008-2014). The macroeconomic development caused a drastic drop in activity in all economic sectors of the European Union and led to a significant reduction in energy consumption. Greece is a prime example where the crisis hit the economy exceptionally hard and in turn, led to a significant decrease in energy consumption (Tsagkari 2020). Similarly, the steady increase of energy consumption in Spain came to a halt when the high energy-consuming construction sector collapsed under the pressure of the economic crisis (Campos-Martín et al. 2020). In the recent phase (2015-2019), the European ambitions for a sustainable energy transition came further into fruition, as renewable energy sources surpassed nuclear energy and solid fossil fuels, which dropped to an all-time low of 10.69% in 2019. Yet, liquid fossil fuels (oil and petroleum) experienced a renaissance in Europe during the recovery from the economic crisis, primarily because of a surge of fuel consumption in transport, and remain the most important energy sources in the European Union (Thomas and Rosenow 2020). Over the last two decades, the energy mix composition changed only slowly, illustrating the inertia inherent in the development of the European energy sector.

Going into more detail of the particular sources in the energy mix, the most evident observation of the long-term development is the dominance of oil and petroleum products, accounting for 34.6% to 38.3% of gross inland consumption during the time between 2000 and 2019. One of the main factors contributing to this dominance is the transport sector, where oil and petroleum products are omnipresent as fuels for combustion engines in cars, trucks, ships, and airplanes. The transition from conventional combustion technologies to sustainable alternatives is facing major challenges (Tagliapietra et al. 2019; Dominković et al. 2018), so the slow developments in the transport sector are upholding oil and petroleum products as the most important energy source in the European Union. Furthermore, particularly in Southern Europe, oil had (Italy, Spain, or Portugal), or still has (Cyprus and Greece) made up a significant share in electricity generation.

The second most important energy source is natural gas accounting for 21% to 25% of gross inland consumption in the last two decades and used primarily for heating and electricity production. As the combustion of natural gas emits less CO_2 than oil and has a far better greenhouse gas balance compared to solid fossil fuels, discussions about the use of natural gas as a bridge technology for the energy transition are ongoing (Szabo 2021; Mac Kinnon et al. 2018). However, the role of natural gas as a vital part of the energy transition is contested, as the controversial debates about the integration of gas infrastructure projects on the list of Projects of Common Interests of the EU have shown (CAN Europe 2021). These discussions showcase not only the relevancy but also the divisiveness between actors, of the future role of natural gas in the energy mix (Levoyannis 2021).

Becoming more unpopular in light of recent developments in energy and climate policy, solid fossil fuels such as hard coal and lignite have been on a downward trend since 2015, from 15% down to 10% of gross inland consumption in the European Union. To advance their energy transitions and reduce CO_2 emissions, most EU countries announced a coal phase-out and so contributed to the decline of solid fossil fuels (Rentier et al. 2019). However, a few EU members such as Poland or Romania, are still heavily invested in solid fossil fuels, as they have large domestic resources of coal and lignite that can be used for cheap electricity production, and secure jobs in local economies (see Zoll 2020; Buzogány and Davidescu 2022).

Serving as an energy source mainly for the electricity baseload, the share of nuclear energy stayed at almost the same level throughout the last two decades. Still, a slow decline from 14% to 12.8% can be observed, resulting from several nuclear phase-outs, for example in Germany (Jahn and Korolczuk 2012), Lithuania (Gaigalis et al. 2013), and Italy (see Di Nucci and Russolillo 2020) due to domestic concerns about safety in the aftermath of the 2011 Fukushima Daiichi nuclear disaster and issues regarding nuclear waste disposal.

Lastly, the development of renewables can be characterized as a constant increase: from being the least important energy source that only accounted for 5.7% of gross inland consumption, to overtaking nuclear heat in 2015 and solid fossil fuels in 2017, to become the third most important energy source in the European energy mix with 15.3% of gross inland consumption. Progress in renewable energy technology, raising concerns about climate change followed by measures to decarbonize the energy sector, as well as energy and climate policy developments at international and European levels, supported the scaling-up of renewables during the last decade (Kanellakis et al. 2013; Sen and Ganguly 2017; Pacesila et al. 2016). As a consequence, renewables are the energy source with the most drastic upturn over the time frame, substituting significant shares of other energy sources such as solid fossil fuels.

The long-term development of the energy mix in Europe is influenced by economic, political, and social developments that impact national and European energy policies. Yet, changes in the overall composition of the energy mix tend to be slow due to the inertia of sectoral supply and transport infrastructures that usually have amortization periods of many decades. However, change takes place, as the rising share of renewable energy shows. As renewable energy sources are the key to the energy transition, a closer look into the European developments is crucial for assessment of the transition outcomes.

Renewable Energy

Renewable energy is defined as "energy obtained from naturally repetitive and persistent flows of energy occurring in the local environment" and comprises water, wind, and solar power, as well as biomass and other sources (Twidell and Weir 2015). The use of renewable energy is the foundation of the energy transition as it is necessary to decarbonize the energy system. The share of renewable energy increased steadily over the last 20 years. In 2019, the European Union, plus the United Kingdom, achieved a total share of 19% renewables in gross energy consumption. But the availability and production of renewable energy sources differ significantly among European countries. Renewable energy systems require technical transformations to handle a higher degree of decentralization and volatile energy production. Besides technical elements, political, social, and economic factors are affecting renewable energy development on the national scale, leading to major differences between European countries (Figure 2).

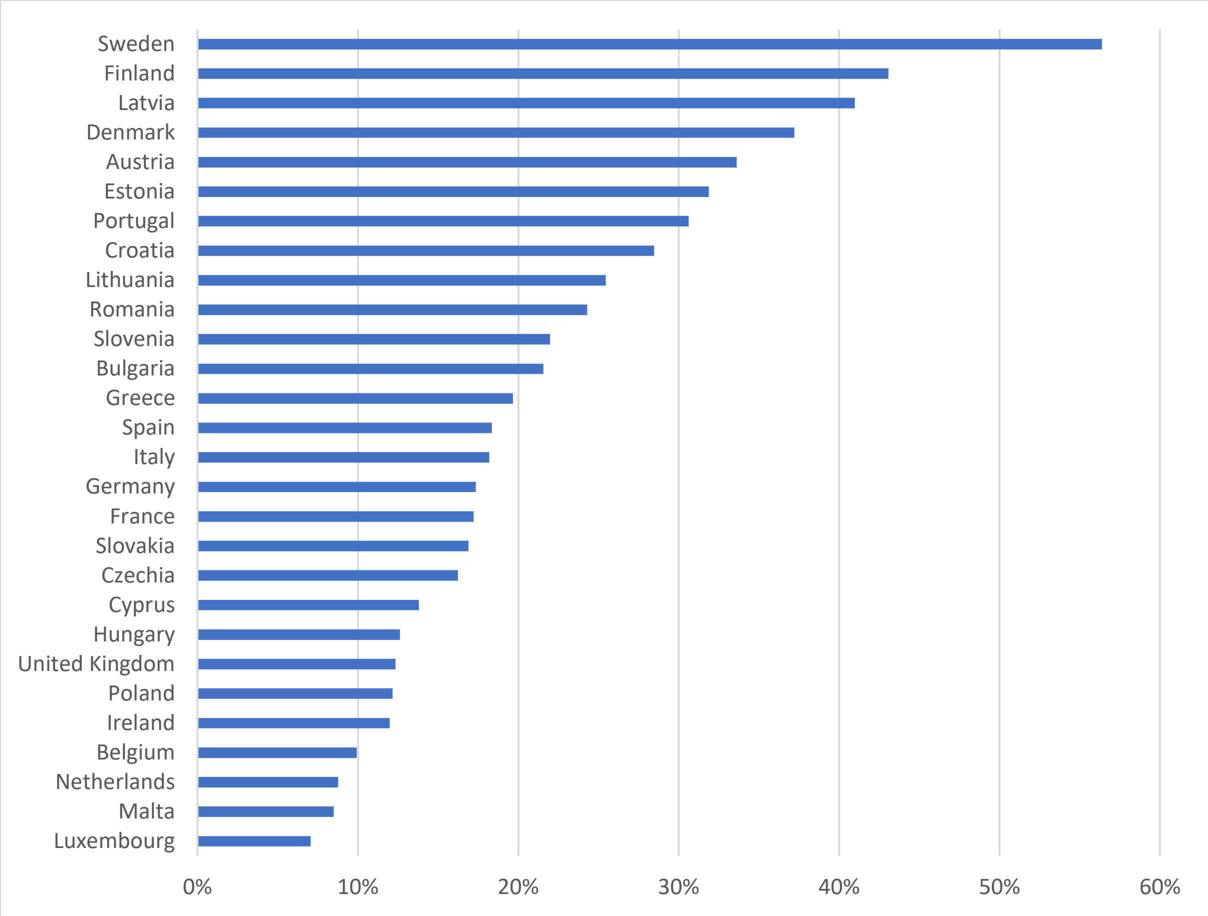

Figure 2: Share of Renewable Energy in Gross Energy Consumption of EU Member States plus the United Kingdom (Eurostat 2022)

These differences concern the total share of renewable energy in the national energy mix, the major renewable energy sources, and the sectors where renewable energy is consumed (Table 1).

Country	Electricity	Transport	Heating/Cooling	Total Share
Belgium	20.83%	6.81%	8.31%	9.92%
Bulgaria	23.51%	7.89%	35.51%	21.56%
Czechia	14.05%	7.83%	22.65%	16.24%
Denmark	65.35%	7.17%	48.02%	37.20%
Germany	40.82%	7.68%	14.55%	17.35%
Estonia	22.00%	5.15%	52.28%	31.89%
Ireland	36.49%	8.93%	6.32%	11.98%
Greece	31.30%	4.05%	30.19%	19.68%
Spain	36.93%	7.61%	18.86%	18.36%
France	22.38%	9.25%	22.46%	17.22%
Croatia	49.78%	5.85%	36.79%	28.47%
Italy	34.97%	9.05%	19.70%	18.18%
Cyprus	9.76%	3.32%	35.10%	13.80%
Latvia	53.42%	5.11%	57.76%	40.97%
Lithuania	18.79%	4.05%	47.36%	25.46%
Luxembourg	10.86%	7.65%	8.71%	7.05%
Hungary	9.99%	8.03%	18.12%	12.61%
Malta	8.04%	8.69%	25.69%	8.49%
Netherlands	18.22%	12.51%	7.08%	8.77%
Austria	75.14%	9.77%	33.80%	33.63%
Poland	14.35%	6.12%	15.98%	12.16%
Portugal	53.77%	9.09%	41.65%	30.62%
Romania	41.71%	7.85%	25.74%	24.29%
Slovenia	32.63%	7.98%	32.16%	21.97%
Slovakia	21.94%	8.31%	19.70%	16.89%
Finland	38.07%	21.29%	57.49%	43.08%
Sweden	71.19%	30.31%	66.12%	56.39%
United Kingdom	34.77%	8.86%	7.84%	12.34%
EU-28	34.17%	8.89%	20.55%	18.88%

Table 1: Share of Renewable Energy in Different Sectors (Eurostat 2022)

The country with the highest renewable energy share in the European Union is Sweden. As already described in the section on oil and natural gas, the energy policy of Sweden has been aimed at a reduction of import dependency since the 1970s and introduced renewable energy early on to address this issue, making the country a frontrunner in renewable energy development. Almost two-thirds of renewable energy is produced by using hydro power, followed by wind. In total 71.19% of electricity is powered by renewable energy. This is only topped among EU members by Austria, with 75.14% of electricity from renewable sources, mainly from large hydropower plants (see Wenz 2020). With a large lead over other European countries, Sweden is the leader in renewable energy consumption in the transport sector with a share of 31.3%. This can be attributed to the use of biofuels and increasing numbers of electric vehicles powered by renewable electricity, as well as electrified rail transport. In the heating sector, Sweden is also the number one in Europe after transforming residential heating systems from fossil fuel-based technology to biomass-based district heating and electric heat pumps, powered by renewable electricity (see Johansson 2021).

But what about the other end of the scale? Here, we find that the Netherlands has one of the lowest shares of renewable energy in the European Union, with only 8.77% in 2019. A significant factor in this small share is that the natural gas reserves of the Netherlands can secure energy supply until at least 2030. Even if renewable energy policies have been part of the Dutch energy policy since the early 1990s, the abundance of fossil resources has damped high political ambitions in renewable energy development until climate change became more salient on the political agenda (see Musch 2020). Renewables accounted for 18.79% of electricity in the year 2019, of which almost half was generated by wind turbines. Due to its geographical location at the North Sea, the Netherlands has a lot of potential for offshore wind parks and the development of the renewable energy industry. Wind power, therefore, has been identified as a priority area for the energy strategy of the Dutch government. In the transport sector, 12.51% of energy consumption is covered by renewable energy and so the Netherlands is above the European average of 8.8% in this sector. The largest deficit can be found in the heating sector, with a renewable share of only 7.08%. The heating sector is dominated by natural gas, for example in the form of gas-fired combined heat and power plants, which also receive governmental support via tax exemptions (see Musch 2020). Around 90% of Dutch households are connected to the natural gas grid, supplied by domestic reserves and therefore major transformative efforts are needed to increase the share of renewable energy in the heating sector (Jansma et al. 2020). The comparison of the Netherlands and Sweden shows, that contextual factors impact the development of renewable energy on a national scale. While Sweden was able to increase their renewable energy share through political ambitions to reduce import dependency on fossil fuels, the Netherlands has abundant natural gas reserves, triggering lock-in effects that hindered large-scale development of renewables, as natural gas was affordable and could be supplied without depending on imports.

Despite the national differences in the energy mixes, renewable energy is continuously on the rise in Europe. But a further intensive increase is necessary to achieve the goal of the European Union to become climate-neutral by 2050. The decarbonization of electricity production, transport, heating, and industry by direct and indirect electrification requires a vast expansion of renewable energy production in every Member State to supply the necessary electricity. Even with renewable energy on the rise in Europe, many technical, economic, political, and social challenges in the context of renewable energy development remain, ranging from the international to the local scale.

3. Transition Outcomes

To take stock of the transition outcomes, a scoring system has been developed to compare the achievements made by the EU member states since 2000. The scoring summarizes how member states performed in achieving the objectives of the energy transition. The objectives are to transform the energy system from the use of fossil fuels to sustainable energy sources. This, in turn, should reduce greenhouse gas emissions to mitigate the effects of climate change. These two intertwined objectives are therefore operationalized to assess the outcomes of the energy transition.

After observing the data of the long-term energy mix development of the member states since 2000, four distinct development paths towards a sustainable energy system were identified. The first path, the advanced transition path, includes member states where renewable energy is competing with fossil fuels for the lead in the energy mix. Renewables are on the brink of becoming the most important energy source across all sectors of the energy system. In the European Union, this path can be observed in Denmark and Latvia. Another variation of this path can be observed in Finland and Sweden, where renewables are backed by nuclear power in substituting fossil fuels as the dominant energy source.

The second path describes member states with an emerging transition, where a significant increase in the share of renewable energy occurred in the time frame from 2000 to 2019, and started to substitute fossil fuels in the energy mix. Yet, fossil fuels are still the dominant energy source and major additional developments are needed to transform the energy system. This path can be observed in Austria, Croatia, Italy, and Portugal. Again, a variation of this path exists and can be observed in Germany and Lithuania. In these two countries, a significant increase of the renewable energy share occurred in parallel to a decline of nuclear power in the context of national phase-outs. Therefore, renewable energy substituted nuclear power instead of fossil fuels.

The third path includes countries with a restrained transition. A restrained transition is characterized by a slight increase, but overall low level, of renewable energy that substitutes a minor amount of fossil fuels that are still by far the most dominant energy source. The transition process is slow-paced and major developments are needed to transform the energy system. This path can be observed in Estonia, Greece, and Ireland. Besides the original path, two other variations can be identified. In Bulgaria, Czech Republic, Hungary, Slovakia, Slovenia, Spain, and Romania, nuclear power plays an important role in the energy system, alongside fossil fuels and a low but increasing share of renewable energy. In the third variation of the third path, the share of nuclear power is steadily declining. This is the case in the Member State of Belgium and in the United Kingdom, where the decline of nuclear power is substituted by a slow increase of renewable energy and stabilized by the use of fossil fuels.

The fourth path describes countries that have difficulties in the transition process and experience stagnation. In these member states, fossil fuels are the most dominant energy source and only marginal developments of renewable energy without significant impact on the energy mix can be observed. These states are Cyprus, Luxembourg, Malta, the Netherlands, and Poland.

While the long-term development of the energy mix is an important factor, additional evidence is needed to assess the progress of the energy transition. The ultimate goal is the reduction of greenhouse gas (GHG) emissions, therefore this aspect has to be considered when evaluating the transition outcomes of European states. To assess the impact of the developments in the energy systems, data of the GHG emissions per capita is used instead of the total emissions to allow a fair comparison between countries with different populations. In 2019, the average emissions of the EU-27 plus the United Kingdom was 8.2 tons of CO2-equivalents per capita (tCO_2eq), ranging from 20.3 tCO_2eq in Luxembourg to 5.2 tCO_2eq in Sweden. These numbers represent the most recent picture of the emissions of European countries and show which countries are the biggest GHG emitters. But it is also important to look at the long-term developments of national emissions, to assess the outcomes of the energy transition. Comparing the annual national GHG emissions in 2000 and 2019 sheds light on reductions achieved by the transition of the energy system. Of the observed countries, 23 of 28 have reduced their annual GHG emissions, four have recorded an increase and one country has the same annual GHG emissions in 2019 as in 2000. The reductions range from 5.7 tCO_2eq per capita in Denmark (from 13.8 tCO_2eq/capita in 2000 to 8.1 tCO_2eq/capita in 2019) to lower reductions of 0.5 tCO_2eq per capita in Hungary and Romania. The highest increase in annual GHG emissions is shown by Lithuania which emitted 1.8 tCO_2eq per capita more in 2019 than in 2000 (Figure 3).

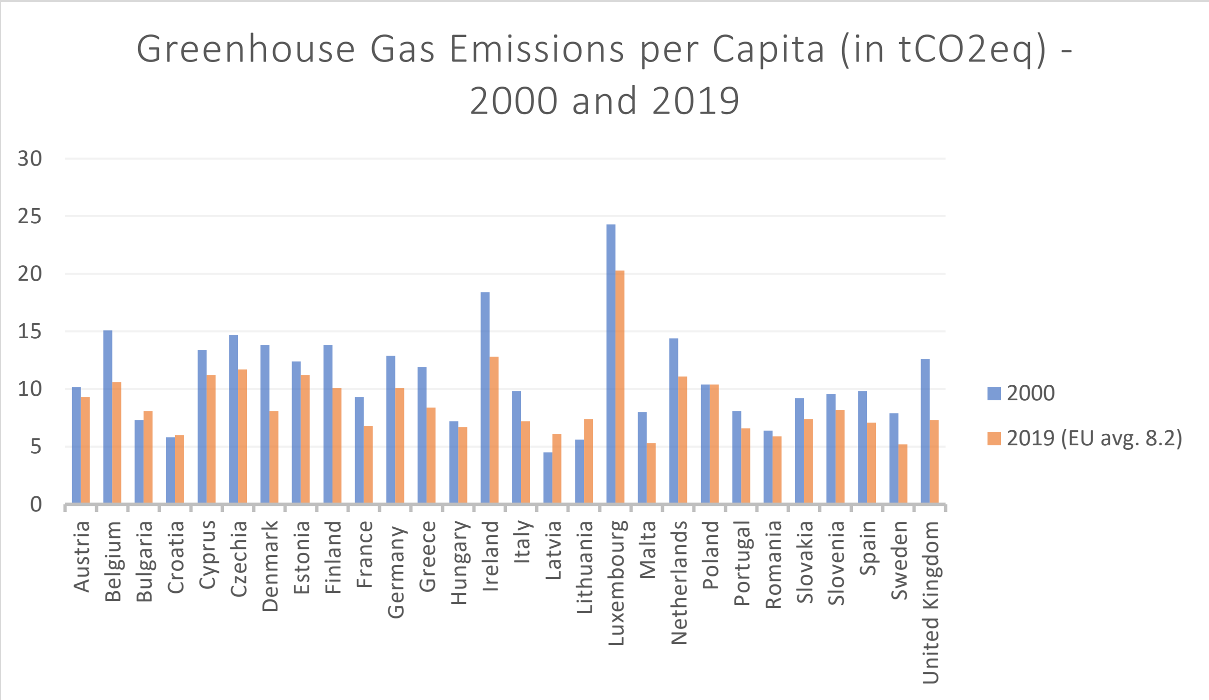

Figure 3: Annual Greenhouse Gas Emissions per Capita of the EU Member States plus the United Kingdom in 2000 and 2019, (Eurostat 2021b)

In total, three aspects constituting the transition outcome were established: the transition path based on the long-term development of the energy mix, the most recent GHG emissions per capita, and the reduction of GHG emissions per capita over the last two decades. These aspects are transferred into a scoring system providing a ranking of European countries based on their transition outcomes (Table 2). The scores range from 6 points, indicating an advanced transition with significant impacts on GHG reductions, to 1 point, indicating a stagnant transition with no significant impacts on GHG emissions. The transition pathway was emphasized in the scoring system. This gives more weight to the development of the countries' energy mixes towards a sustainable energy system, which is the focal point of the comparison.

Transition Pathway	**CO2 per Capita (2019)**	**Annual Reduction of GHG-emissions**
Advanced (4P)	Below Average or Average (1P)	Yes (1P)
Emerging (3P)		
Restrained (2P)	Above Average (0P)	No (0P)
Stagnant (1P)		

Table 2: Scoring System for the Transition Outcomes

If the scoring system is applied to the EU member states and the United Kingdom, an overview of the transition outcomes is generated and a comparison of the observed countries is possible (Table 3). Denmark and Sweden have the highest possible score and are therefore the countries with the most advanced transition, including significant impacts on GHG emissions. Most countries achieved a score in the midrange between 3 and 4, indicating that the majority of European countries have made progress, but major additional efforts are needed to advance the transition of the energy system and ultimately reduce more GHG emissions. Only four countries have achieved a low score of 1 or 2, indicating major challenges in transforming the energy system and a lack of progress in reducing GHG emissions.

Member State	Score	Type of Transition	Reduction of Total GHG-Emissions since 2000 (in tCO2-eq per Capita)	CO2 per Capita (Avg.: 8.2 tCO2-eq)
Denmark	6	Advanced Transition	Yes (-5.7)	Below Average (8.1)
Sweden	6	Advanced Transition	Yes (-2.7)	Below Average (5.2)
Latvia	5	Advanced Transition	No (+1.6)	Below Average (6.1)
Finland	5	Advanced Transition	Yes (-3.7)	Above Average (10.1)
Italy	5	Emerging Transition	Yes (-2.6)	Below Average (7.2)
Portugal	5	Emerging Transition	Yes (-1.5)	Below Average (6.6)
France	5	Emerging Transition	Yes (-2.5)	Below Average (6.8)
Austria	4	Emerging Transition	Yes (-0.9)	Above Average (9.3)
Croatia	4	Emerging Transition	No (+0.2)	Below Average (6.0)
Lithuania	4	Emerging Transition	No (+1.8)	Below Average (7.4)
Germany	4	Emerging Transition	Yes (-2.8)	Above Average (10.1)
Hungary	4	Restrained Transition	Yes (-0.5)	Below Average (6.7)
Romania	4	Restrained Transition	Yes (-0.5)	Below Average (5.9)
Slovakia	4	Restrained Transition	Yes (-1.8)	Below Average (7.4)
Slovenia	4	Restrained Transition	Yes (-1.4)	Average (8.2)
Spain	4	Restrained Transition	Yes (-2.7)	Below Average (7.1)
United Kingdom	4	Restrained Transition	Yes (-5.3)	Below Average (7.3)
Greece	3	Restrained Transition	Yes (-3.5)	Above Average (8.4)
Malta	3	Stagnant Transition	Yes (-2.7)	Below Average (5.3)
Ireland	3	Restrained Transition	Yes (-5.6)	Above Average (12.8)
Czech Republic	3	Restrained Transition	Yes (-3.0)	Above Average (11.7)
Bulgaria	3	Restrained Transition	No (+0.8)	Below Average (8.1)
Belgium	3	Restrained Transition	Yes (-4.5)	Above Average (10.6)
Estonia	3	Restrained Transition	Yes (-1.2)	Above Average (11.2)
Cyprus	2	Stagnant Transition	Yes (-2.2)	Above Average (11.2)
Luxembourg	2	Stagnant Transition	Yes (-4.0)	Above Average (20.3)
Netherlands	2	Stagnant Transition	Yes (-3.3)	Above Average (11.1)
Poland	1	Stagnant Transition	No (0.0)	Above Average (10.4)

Table 3: Transition Outcome Ranking of the EU Member States and the United Kingdom

It is not surprising that countries characterized by an advanced transition path also perform well in reducing their GHG-emission, as the transition path implies an energy system development towards energy sources with a low carbon footprint, such as renewables, but also nuclear energy. Yet the results show that the defined transition paths do not exclusively determine reduction of GHG emissions and a lower level of emissions per capita. Countries such as Hungary, Romania, Slovakia, Spain, the UK, and Malta have all reduced their GHG emissions over the past 20 years and are emitting less CO_2 per capita than average. This can be attributed to less intensive economic activity and a focus on natural gas in their energy systems, which is less CO_2-intensive than coal. While these attributes can lead to significant reductions in GHG emissions, natural gas is still considered a bridge fuel, meaning it should be used for an interim stage before renewable energy (or nuclear) becomes the major component of the energy mix. As the threat of technological lock-in effects is still pending over the use of natural gas, the ranking of these countries on the lower ranks is justified, as the course for deep decarbonization is not finally set.

As for the method of this analysis, there are downsides to the approach used in the evaluation of the transition outcomes. For example, renewable energy projects that are in the planning or building process are not included in the transition pathways. This information could give more context about the immediate future of the energy mix development, but a lack of standardized data and uncertainties as to which projects will be finalized led to the decision to use only the official data on the energy mix composition. Additionally, the use of the average CO_2 emission per capita as a threshold to decide on the transition outcome can be discussed. While the long-term goal of decarbonization would be to achieve GHG emissions of near-zero tons CO_2-equivalents per capita, there is no definite number deemed necessary to be achieved by 2020. The approach of using the EU average circumvents this problem and allows quantification of a high and low quantity of CO_2 emissions that can be used to evaluate and compare the European countries, based on their overall achievements. Overall, the comparison of the national transition outcomes is a complicated task, as every single country has a distinct energy policy, historical path dependencies, and geographic and economic opportunities. In using broader categories and comparable numbers, the comparative approach deals with both the uniqueness of national energy systems and the overall picture of the European energy transition.

4. Explaining transition pathways

If it comes to explanations for the significant differences in transition outcomes, many scholarly approaches concentrate either on policy instruments (Gawel et al. 2017) or on structures (Lockwood et al. 2017). We will combine both approaches, as that we regard governance arrangements and policy instruments as important, but embedded in long-term structural developments. These developments are shaped by geographic circumstances, economic legacies as well as critical policy decisions that induced path-dependencies by itself.

Geographical and political path-dependencies

Path dependencies refer to both economic-geographical conditions and critical political decisions that became, as *critical junctures*, structural determinants for further development. Economic-geographical conditions include domestic fossil fuel deposits as well as conditions for renewable energy plants. For example, while large coal deposits in Poland (Zoll 2020) may explain the blockade of the energy transition, long experience with hydropower in Austria (Wenz 2020) or Sweden (Johansson 2021) may explain the more favorable situation of these countries. Crucial decisions concern long-term government strategies such as the French program to use nuclear energy in the 1970s (Boquillon & Evrard 2022) or the British decision to close coal mines on a large scale in the 1980s (Lockwood et al. 2020).

Economic legacies

This is particularly about the dependence of energy systems on fossil fuels. Another factor will be the importance of the industrial sector of the economy. Our hypotheses address both aspects. We consider the size of the industrial sector and the dependence on domestic fossil fuels as unfavorable structural conditions for a low-carbon energy transition, while both the dependence on fossil fuel imports and the size of the tertiary sector of an economy can be considered as drivers for a low-carbon transition.

Governance and Policy Instruments of Transition

Governance arrangements and policy instruments for energy transitions are multifaceted, as every state's energy system is embedded in unique institutional structures, political dynamics, and historical path dependencies. Every country developed an individual policy mix of incentive-based instruments, regulatory policies, internalizing instruments, and soft governance as a response to their peculiar challenges and objectives. In the following, concepts and examples of the different policy instruments used in the governance of energy transitions are presented.

We hypothesize that the success of policy instruments and governance arrangements depends in particular on the stability of these instruments and arrangements, as stability leads to stable expectations on the part of investors and consumers. Moreover, we should not forget the interdependence of structures and policies.

By offering benefits to participating actors, incentive-based instruments stimulate voluntary behavioral change by providing subsidies, grants, loans, tax expenditures, and more (Bemelmans-Videc et al. 1998). The most common incentive-based instruments used in energy transitions are support schemes for renewable energy, which are either based on price (e.g. feed-in-tariffs) or quantity (e.g. auction and tendering schemes). Feed-in-tariffs (FITs) are implemented and managed by national authorities and guarantee renewable energy producers access to the electricity grid and the right to sell their generated electricity at a fixed price (Goldemberg 2012). National authorities also organize auctions by a call for tenders for a specific capacity of renewable energy. Developers can submit a bid for the construction and management of a renewable energy project. In the auction, the government will grant the project to the bid with the lowest price, ensuring public funding is used in the most effective way

(Ferroukhi et al. 2015). In Europe, both types of incentive-based instruments are used to foster renewable energy development. In Germany, a FIT was already introduced in the 1990s to support renewable energy development, which at this time was a niche technology and not competitive in the electricity market. Through the FIT, a crucial increase and cost-reduction of renewable energy production could be realized and the technology became economically competitive in the market (see Kemmerzell 2022). Many countries combine different incentive-based instruments for renewable energy development. Spain has a FIT in force but also used auction schemes to manage large-scale projects to speed up the increase of the renewable energy share to reach their target of the Renewable Energy Directive in time (see Campos-Martín et al. 2020). Similarly, tender schemes are used to develop offshore wind parks in Denmark, while onshore wind energy is managed solely through FITs (see Dyrhauge 2022). After introducing a rather ineffective and unsuccessful Renewables Obligation in the United Kingdom, a system based on FITs in combination with Contracts for Differences was implemented for renewable energy (see Lockwood et al. 2020). Furthermore, the change from an obligatory scheme to a contract for difference feed-in-tariff in the United Kingdom is a prime example of how incentive-based instruments are changed and adapted to new contexts and challenges.

Another type of policy instrument for the governance of energy transitions is regulatory policy-making. This type of instrument is characterized by the implementation via hierarchical government interventions to set standards or prohibit certain technologies. For example, Italy defined minimum energy performance standards for buildings to achieve their national energy efficiency targets, set out in the European Energy Efficiency Directive (see Di Nucci and Russolillo 2020). Regulatory instruments to prohibit technologies include the phasing-out of coal and nuclear power. The first Member State to phase out coal was Belgium, which closed the last coal-fired power plant in 2016 (see van de Graaf et al. 2020), followed by Sweden and Austria in 2020. Other countries such as Germany, Finland, and Slovakia will follow in the future and have already laid out the legislative foundations for the phase-out. An example of a regulatory policy in the transport sector is the mandatory share of biofuels implemented in Finland to reduce emissions and introduce renewable forms of fuels (see Hildén and Kivimaa 2020). Regulatory policy-making also supplements incentive-based instruments, for example by requiring utility companies operating the electricity grid to feed in the electricity from renewable energy producers, as is the case in Finland (see Hildén and Kivimaa 2020) and many other European countries. Additionally, regulations can be used to facilitate and accelerate authorization procedures for renewable energy projects, such as the so-called Single Authorization in Italy (see Di Nucci and Russolillo 2020). Additionally, regulatory policies emerge from the European level and then have to be implemented in the member states. For example, the Renewable Energy Directive from 2009 set out legally binding targets for the national share of renewable energy to be accomplished by the year 2020. But target setting can only be considered a regulatory measure if non-compliance with the target is sanctionable. When non-compliance has no direct consequences, it is considered a soft governance measure.

Soft governance describes measures such as information sharing, benchmarking, guidelines, and recommendations that are non-binding in nature, meaning that non-compliance is not sanctionable (Knodt et al. 2020). Soft governance is ubiquitous in energy governance and comes in a variety of forms. In the Netherlands, the government and its leading advisory council organized public consultations to integrate citizens' opinions on the future of the national energy policy (see Musch 2020). In the Czech Republic, the government established Energy Consultation and Information Centers that inform the public about investment opportunities in renewable energy, energy efficiency measures, and alternative heat supply (see Osička et al. 2020b). In Ireland, education programs were developed to achieve behavior changes in transport, informing about sustainable ways of traveling (see Torney 2020). While soft governance might not lead to immediate or grand scale change due to its non-binding nature, these measures can be a first step towards later regulations.

Internalizing instruments incorporate external costs that carbon emissions cause in the future and aim to foster immediate emission reductions through market mechanisms. The most prominent type of internalizing instruments are cap-and-trade schemes, such as the Emissions Trading Scheme of the European Union (EU ETS). In the EU ETS, a cap limits the amount of emissions of companies. The EU allocates a fixed number of allowances to companies that can be used to permit greenhouse gas emissions or can be sold to other participants of the scheme that need more allowances than they received. After a determined time frame, more allowances are removed from the market, increasing the price of emitting greenhouse gases (Ellerman et al. 2010). Carbon taxes are another form of internalizing instrument, typically levied on the use of specific energy carriers, such as coal, oil, and natural gas. In contrast to emission trading schemes, where the price of emitting is determined by market forces, carbon taxes are fixed (Goldemberg 2012). Quite a few member states of the EU are levying carbon taxes, for example, Sweden has a carbon tax on transportation fuels, agriculture, and industries outside of the EU ETS (see Johansson 2021). Similarly, in Ireland, the purchase of solid fossil fuels, natural gas, oil and petroleum products, and peat is taxed on basis of carbon emissions. Industries that are already part of the EU ETS are exempt from these taxes to avoid a double burden for affected companies (see Torney 2020). National carbon taxes, therefore, mostly complement the EU ETS by internalizing the carbon emissions costs of actors outside of the European system.

An integrated approach for the explanation of transition outcomes

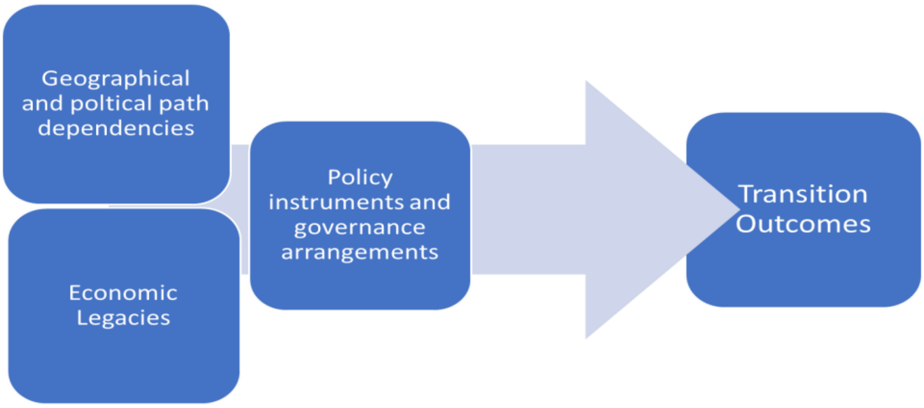

Figure 4: Structural Model of Transition Outcomes

Conclusion: An Energy Mix and Energy Governance for Climate Neutrality?

European energy systems are in a continuous process of change. The share of renewable energy has increased rapidly in the last 20 years, underlining the growing importance of carbon-neutral energy sources. But to achieve a climate-neutral energy system, a massive expansion of renewables is necessary, which poses major technological, economic, social, and political challenges. While the utilization of renewables in the electricity sector is far advanced, they also have to be used to decarbonize sectors and applications that cannot be electrified directly. This indirect electrification will require even more renewable energy capacities, for example, to produce renewable hydrogen and synthetic fuels for industry and transport sector use. For some member states, nuclear power is another option to decarbonize the energy system, e.g. in Romania and Slovakia (Buzogány and Davidescu 2022; Mišík and Oravcová 2020), where energy discourses explicitly frame nuclear energy as a technology of the energy transition. Nuclear power has provided a constant baseload of electricity throughout the last 20 years. However, due to security and environmental risks, the energy source is politically and socially contested, leading to a divide between members states that want to expand or phase-in nuclear power and member states that reject the use of nuclear power or want to phase out the technology. By contrast, European states widely consent on the topic of reducing and ultimately phasing-out fossil fuels. Looking at solid fossil fuels, coal, and lignite, there is a significant retreat in the EU member states' energy mix and a majority of states with completed or announced phase-outs, due to the negative climate impact of the energy source (IEA 2021). In contrast, oil still plays a crucial role in the European energy system and has the highest share of all sources in the energy mix, due to its dominance in the transport sector. Natural gas will also remain an important element of the energy system and its relevance could even increase as it is discussed as being a necessary part of the energy transition by using it as a bridge fuel. While the share of fossil fuels is declining, its significance in the energy system is still exceptionally high and major efforts in renewable energy and end-use technology development are needed to substitute solid fossil fuels, oil and petroleum, and natural gas.

On the EU level, the overlap of two jurisdictions characterizes energy governance. While climate policy is basically supranational, energy policy largely remains a domain of the member states. As long as energy policy is a national competence, there will be a plurality of governance instruments. However, the common goal of climate neutrality and the supranational character of climate policy could strengthen the importance of climate mitigation instruments, i.e. the European ETS and the proposed ETS 2. That would not come without conflicts and disadvantages, as a concentration on CO_2 pricing yields issues of distributive fairness and incentives. Particularly when it comes to asset-specific investments, e.g. in infrastructures, price-signals to private investors might be insufficient or misleading as governance instruments. Following the raising of European targets to achieve climate neutrality in 2050, it is clear that these cannot be achieved through emissions trading alone, not even by extending trading to the transport and heat sectors. Achieving the targets requires a massive expansion of renewable energies as well as an increase in energy efficiency. Here, the EU is trying to enrich the soft governance in the energy sector with harder elements of governance in the *Fit for 55 package* (Knodt and Ringel 2022). The achievement of the goals will depend on the achievement of tougher governance in the EU's energy legislation, as well as on the further development of emissions trading. Furthermore, the impacts of the recent Russian invasion in Ukraine cannot yet be assessed, but it is safe to say that it will change the European energy policy development and will have significant impacts on the way energy policy is approached in the coming years.

References

Bemelmans-Videc, M.-L., Rist, R. C., & Vedung, E. (1998). Policy Instruments: Typologies and Theories. In M.-L. Bemelmans-Videc & Ray, C. Rist, Vedung, Evert (Eds.), *Carrots, Sticks & Sermons*: *Policy Instruments & Their Evaluation* (pp. 21–58). Routledge.

Boasson, E. L., Leiren, M. D., & Wettestad, J. (2021). Comparative assessments and conclusions. In E. L. Boasson, M. D. Leiren, & J. Wettestad (Eds.), *Comparative Renewables Policy*: *Political, Organizational and European Fields* (pp. 219–239). Abingdon, New York: Routledge.

Bocquillon, P. & Evrard, A. (2021). Energy Governance in France. A Nuclearized Socio-technical Regime “in transition”? in: M. Knodt & J. Kemmerzell (Eds.), Handbook of Energy Governance in Europe. Cham: Springer International Publishing; Imprint: Springer.

Brüggemeier, F.-J. (2018). *Grubengold: Das Zeitalter der Kohle von 1750 bis heute* (1st ed.). München: C.H.Beck.

Buzogány, A., & Davidescu, S. (2022). Energy Governance in Romania. In M. Knodt & J. Kemmerzell (Eds.), *Handbook of Energy Governance in Europe*. Cham: Springer International Publishing; Imprint: Springer.

Campos-Martín, J. M., Crespo, L., & Fernandez, R. M. (2020). Energy Governance in Spain. In M. Knodt & J. Kemmerzell (Eds.), *Handbook of Energy Governance in Europe* (pp. 1–36). Cham: Springer International Publishing; Imprint: Springer.

CAN Europe. (2021). Candidate projects for the 5th PCI list: a final push for fossil gas? - CAN Europe. https://caneurope.org/candidate-projects-5th-pci-list-briefing-push-fossil-gas/. Accessed 12 May 2021.

Cherif, R., Hasanov, F., & Pande, A. (2021). Riding the Energy Transition: Oil beyond 2040. *Asian Economic Policy Review, 16*, 117–137. doi:10.1111/aepr.12317.

Di Nucci, M. R., & Russolillo, D. (2020). Energy Governance in Italy. In M. Knodt & J. Kemmerzell (Eds.), *Handbook of Energy Governance in Europe* (pp. 1–32). Cham: Springer International Publishing; Imprint: Springer.

Dominković, D. F., Bačeković, I., Pedersen, A. S., & Krajačić, G. (2018). The future of transportation in sustainable energy systems: Opportunities and barriers in a clean energy transition. *Renewable and Sustainable Energy Reviews, 82,* 1823–1838. doi:10.1016/j.rser.2017.06.117.

Dyrhauge, H. (2020). Energy Governance in Denmark. In M. Knodt & J. Kemmerzell (Eds.), *Handbook of Energy Governance in Europe* (pp. 1–26). Cham: Springer International Publishing; Imprint: Springer.

Ellerman, A. D., Convery, F. J., & Perthuis, C. de. (2010). *Pricing carbon: The European Union emissions trading scheme* (1st ed.). Cambridge: Cambridge Univ. Press.

Eurostat. (2021a). Complete Energy Balances (nrg_bal_c). https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_bal_c. Accessed 4 November 2021.

Eurostat. (2021b). Greenhouse gas emissions per capita. https://ec.europa.eu/eurostat/databrowser/view/t2020_rd300/default/table?lang=en. Accessed 12 January 2022.

Eurostat. (2021c). Natural gas supply statistics. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Natural_gas_supply_statistics#Consumption_trends. Accessed 4 November 2021.

Eurostat. (2021d). Oil and petroleum products - a statistical overview. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Oil_and_petroleum_products_-_a_statistical_overview#Production_of_crude_oil. Accessed 3 November 2021.

Eurostat. (2022). SHARES (Renewables) - Energy - Eurostat. Eurostat. https://ec.europa.eu/eurostat/web/energy/data/shares. Accessed 23 March 2022.

Ferroukhi, R., Hawila, D., Vinci, S., & Nagpal, D. (2015). *Renewable Energy Auctions: A Guide to Design*. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/Jun/IRENA_Renewable_Energy_Auctions_A_Guide_to_Design_2015.pdf.

Fischer, S. (2011). *EURATOM und die Energiewende: Szenarien für die Zukunft des europäischen Atomvertrags*. Arbeitspapier Forschungsgruppe EU-Integration (Arbeitspapier der FG 1, 2011/Nr. 03). Berlin.

Flyvbjerg, B. (2017). Introduction: The Iron Law of Megaproject Management. In *The Oxford Handbook of Megaproject Management* (pp. 1–18).

Fraunhofer IWES. (2015). *The European Power System in 2030: Flexibility Challenges and Integration Benefits: An Analysis with a Focus on the Pentalateral Energy Forum Region. Analysis on behalf of Agora Energiewende*. Analysis. Berlin. https://www.agora-energiewende.de/fileadmin/Projekte/2014/Ein-flexibler-Strommarkt-2030/Agora_European_Flexibility_Challenges_Integration_Benefits_WEB_Rev1.pdf.

Gaigalis, V., Markevicius, A., Katinas, V., Skema, R., & Tumosa, A. (2013). Analysis of energy transition possibilities after the decommission of a nuclear power plant in Ignalina region in Lithuania. *Renewable and Sustainable Energy Reviews, 24,* 45–56. doi:10.1016/j.rser.2013.03.028.

Gawel, E., Strunz, S., & Lehmann, P. (2017). Support policies for renewables: Instrument choice and instrument change from a public policy perspective. In D. Arent et al. (Eds.), The political economy of clean energy transitions, pp. 80–99.

Goldemberg, J. (2012). *Energy: What Everyone Needs to Know* (What Everyone Needs to Know). Oxford: Oxford University Press USA.

Gürsan, C., & Gooyert, V. de. (2021). The systemic impact of a transition fuel: Does natural gas help or hinder the energy transition? *Renewable and Sustainable Energy Reviews, 138,* 110552. doi:10.1016/j.rser.2020.110552.

Hildén, M., & Kivimaa, P. (2020). Energy Governance in Finland. In M. Knodt & J. Kemmerzell (Eds.), *Handbook of Energy Governance in Europe* (pp. 1–28). Cham: Springer International Publishing; Imprint: Springer.

Jahn, D., & Korolczuk, S. (2012). German exceptionalism: the end of nuclear energy in Germany! *Environmental Politics, 21*, 159–164. doi:10.1080/09644016.2011.643374.

Jansma, S. R., Gosselt, J. F., & Jong, M. D. de. (2020). Kissing natural gas goodbye? Homeowner versus tenant perceptions of the transition towards sustainable heat in the Netherlands. *Energy Research & Social Science, 69,* 101694. doi:10.1016/j.erss.2020.101694.

Johansson, B. (2021). Energy Governance in Sweden. In M. Knodt & J. Kemmerzell (Eds.), *Handbook of Energy Governance in Europe* (pp. 1–30). Cham: Springer International Publishing; Imprint: Springer.

Kanellakis, M., Martinopoulos, G., & Zachariadis, T. (2013). European energy policy—A review. *Energy Policy, 62,* 1020–1030. doi:10.1016/j.enpol.2013.08.008.

Kemmerzell, J. (2022). Energy Governance in Germany. In M. Knodt & J. Kemmerzell (Eds.), *Handbook of Energy Governance in Europe*. Cham: Springer International Publishing; Imprint: Springer.

Kemmerzell, J., & Knodt, M. (2021). Dekarbonisierung der Energieversorgung: Der deutsche Kohleausstieg im europäischen Kontext. In Bundeszentrale für politische Bildung (Ed.), *Abschied von der Kohle*: *Struktur- und Kulturwandel im Ruhrgebiet und in der Lausitz* (pp. 58–73). Bonn: Bundeszentrale für politische Bildung.

Knodt, M., & Ringel, M. (2020). European Union Energy Policy: A Discourse Perspective. In M. Knodt & J. Kemmerzell (Eds.), *Handbook of Energy Governance in Europe* (pp. 1–22). Cham: Springer International Publishing; Imprint: Springer.

Knodt, M., Ringel, M., & Müller, R. (2020). 'Harder' soft governance in the European Energy Union. *Journal of Environmental Policy & Planning, 22,* 787–800. doi:10.1080/1523908X.2020.1781604.

Le Maire, B. (2021, October 10). Aufruf von EU-Ministern: Warum Europa Kernenergie braucht. *WELT.* https://www.welt.de/debatte/kommentare/article234330374/Aufruf-von-EU-Ministern-Warum-Europa-Kernenergie-braucht.html. Accessed 15 February 2022.

Levi, M. (2013). Climate consequences of natural gas as a bridge fuel. *Climatic Change, 118,* 609–623. doi:10.1007/s10584-012-0658-3.

Levoyannis, C. (2021). The EU Green Deal and the Impact on the Future of Gas and Gas Infrastructure in the European Union. In M. Mathioulakis (Ed.), *Aspects of the Energy Union*: *Application and Effects of European Energy Policies in SE Europe and Eastern Mediterranean* (1st ed., pp. 201–224, Energy, Climate and the Environment). Cham: Springer International Publishing; Imprint: Palgrave Macmillan.

Lockwood, M., Kuzemko, C., Mitchell, C., & Hoggett, R. (2017). Historical institutionalism and the politics of sustainable energy transitions: A research agenda. Environment and Planning C: Politics and Space, 35(2), 312–333.

Lockwood, M., Mitchell, C., & Hoggett, R. (2020). Energy Governance in the United Kingdom. In M. Knodt & J. Kemmerzell (Eds.), *Handbook of Energy Governance in Europe* (pp. 1–31). Cham: Springer International Publishing; Imprint: Springer.

Mac Kinnon, M. A., Brouwer, J., & Samuelsen, S. (2018). The role of natural gas and its infrastructure in mitigating greenhouse gas emissions, improving regional air quality, and renewable resource integration. *Progress in Energy and Combustion Science, 64*, 62–92. doi:10.1016/j.pecs.2017.10.002.

Mišík, M., & Oravcová, V. (2020). Energy Governance in Slovakia. In M. Knodt & J. Kemmerzell (Eds.), *Handbook of Energy Governance in Europe* (pp. 1–29). Cham: Springer International Publishing; Imprint: Springer.

Musch, E. (2020). Energy Governance in the Netherlands. In M. Knodt & J. Kemmerzell (Eds.), *Handbook of Energy Governance in Europe* (pp. 1–33). Cham: Springer International Publishing; Imprint: Springer.

OECD. (2017). *OECD Environmental Performance Reviews: Estonia 2017* (OECD Environmental Performance Reviews). Paris. https://doi.org/10.1787/9789264268241-en.

Osička, J., Kemmerzell, J., Zoll, M., Lehotský, L., Černoch, F., & Knodt, M. (2020a). What's next for the European coal heartland? Exploring the future of coal as presented in German, Polish and Czech press. *Energy Research & Social Science, 61*, 101316. doi:10.1016/j.erss.2019.101316.

Osička, J., Zapletalová, V., Černoch, F., & Vlček, T. (2020b). Energy Governance in the Czech Republic. In M. Knodt & J. Kemmerzell (Eds.), *Handbook of Energy Governance in Europe* (pp. 1–30). Cham: Springer International Publishing; Imprint: Springer.

Pacesila, M., Burcea, S. G., & Colesca, S. E. (2016). Analysis of renewable energies in European Union. *Renewable and Sustainable Energy Reviews, 56,* 156–170. doi:10.1016/j.rser.2015.10.152.

Rentier, G., Lelieveldt, H., & Kramer, G. J. (2019). Varieties of coal-fired power phase-out across Europe. *Energy Policy, 132*, 620–632. doi:10.1016/j.enpol.2019.05.042.

Safari, A., Das, N., Langhelle, O., Roy, J., & Assadi, M. (2019). Natural gas: A transition fuel for sustainable energy system transformation? *Energy Science & Engineering, 7*, 1075–1094. doi:10.1002/ese3.380.

Schneider, M., & Froggatt, A. (2019). *The World Nuclear Industry Status Report 2019*. Paris, Budapest.

Sen, S., & Ganguly, S. (2017). Opportunities, barriers and issues with renewable energy development – A discussion. *Renewable and Sustainable Energy Reviews, 69*, 1170–1181. doi:10.1016/j.rser.2016.09.137.

Simon, F. (2022, February 2). EU puts green label for nuclear and gas officially on the table. *EURACTIV.com.* https://www.euractiv.com/section/energy-environment/news/eu-puts-green-label-for-nuclear-and-gas-officially-on-the-table/. Accessed 15 February 2022.

Smil, V. (2015). *Power Density: A Key to Understanding Energy Sources and Uses*. MIT Press.

Smil, V. (2021). *Grand Transitions: How the Modern World Was Made*. Oxford University Press.

Stephenson, E., Doukas, A., & Shaw, K. (2012). "Greenwashing gas: Might a 'transition fuel' label legitimize carbon-intensive natural gas development?". *Energy Policy, 46*, 452–459. doi:10.1016/j.enpol.2012.04.010.

Szabo, J. (2021). Natural Gas' Changing Discourse in European Decarbonisation. In M. Mišík & N. Kujundžić (Eds.), *Energy Humanities. Current State and Future Directions* (1st ed., pp. 67–88). Cham: Springer International Publishing.

Szabo, J., Weiner, C., & Deák, A. (2020). Energy Governance in Hungary. In M. Knodt & J. Kemmerzell (Eds.), *Handbook of Energy Governance in Europe* (pp. 1–32). Cham: Springer International Publishing; Imprint: Springer.

Tagliapietra, S., Zachmann, G., Edenhofer, O., Glachant, J.-M., Linares, P., & Loeschel, A. (2019). The European union energy transition: Key priorities for the next five years. *Energy Policy, 132*, 950–954. doi:10.1016/j.enpol.2019.06.060.

Thomas, S., & Rosenow, J. (2020). Drivers of increasing energy consumption in Europe and policy implications. *Energy Policy, 137*, 111108. doi:10.1016/j.enpol.2019.111108.

Torney, D. (2020). Energy Governance in Ireland. In M. Knodt & J. Kemmerzell (Eds.), *Handbook of Energy Governance in Europe* (pp. 1–21). Cham: Springer International Publishing; Imprint: Springer.

Tsagkari, M. (2020). Energy Governance in Greece. In M. Knodt & J. Kemmerzell (Eds.), *Handbook of Energy Governance in Europe* (pp. 1–27). Cham: Springer International Publishing; Imprint: Springer.

Twidell, J., & Weir, A. D. (2015). *Renewable energy resources*. Abingdon, Oxon: Routledge.

van de Graaf, T., Laes, E., & Verbruggen, A. (2020). Energy Governance in Belgium. In M. Knodt & J. Kemmerzell (Eds.), *Handbook of Energy Governance in Europe* (pp. 1–22). Cham: Springer International Publishing; Imprint: Springer.

Verbruggen, A. (2008). Renewable and nuclear power: A common future? *Energy Policy, 36*, 4036–4047. doi:10.1016/j.enpol.2008.06.024.

Wenz, N. (2020). Energy Governance in Austria. In M. Knodt & J. Kemmerzell (Eds.), *Handbook of Energy Governance in Europe* (pp. 1–29). Cham: Springer International Publishing; Imprint: Springer.

World Nuclear Association. (2022). Nuclear Power in the European Union. World Nuclear Association. https://www.world-nuclear.org/information-library/country-profiles/others/european-union.aspx.

Zhang, X., Myhrvold, N. P., Hausfather, Z., & Caldeira, K. (2016). Climate benefits of natural gas as a bridge fuel and potential delay of near-zero energy systems. *Applied Energy, 167*, 317–322. doi:10.1016/j.apenergy.2015.10.016.

Zoll, M. (2020). Energy Governance in the Republic of Poland. In M. Knodt & J. Kemmerzell (Eds.), *Handbook of Energy Governance in Europe* (pp. 1–36). Cham: Springer International Publishing; Imprint: Springer.