CLIMATE CHANGE
58/2024

Development of combustion installations under the EU ETS

Overview and country-level analysis of electricity generation between 2005 and 2019

by:

Charlotte Loreck, Hauke Hermann, Verena Graichen, Roman Mendelevitch
Oeko-Institut, Berlin

as part of a joint project with INFRAS, Zurich

publisher:
German Environment Agency

German Environment Agency

CLIMATE CHANGE 58/2024

EVUPLAN of the Federal Ministry of Economic Affairs and Energy

Project No. (FKZ) 3719 42 505 0

FB001604/ENG

Development of combustion installations under the EU ETS

Overview and country-level analysis of electricity generation between 2005 and 2019

by

Charlotte Loreck, Hauke Hermann, Verena Graichen, Roman Mendelevitch
Oeko-Institut, Berlin

as part of a joint project with INFRAS, Zurich

On behalf of the German Environment Agency

Imprint

Publisher
Umweltbundesamt
Wörlitzer Platz 1
06844 Dessau-Roßlau
Tel: +49 340-2103-0
Fax: +49 340-2103-2285
buergerservice@uba.de
Internet: www.umweltbundesamt.de

Report performed by:
Oeko-Institut e.V
Borkumstraße 2
13189 Berlin

Report completed in:
September 2024

Edited by:
Section V 3.3 Economic Aspects of Emissions Trading, Auctioning, Evaluation
Alexandra Zirkel, Claudia Gibis

DOI:
https://doi.org/10.60810/openumwelt-7634

ISSN 1862-4804

Dessau-Roßlau, December 2024

Abstract: Development of combustion installations under the EU ETS

The generation of electricity and heat is the largest single activity covered by the EU Emissions Trading System (EU ETS). Due to the interconnectedness, the difference in the emission intensity of the different fuels and their configuration in a competitive marginal cost pricing market, power plants had a large potential for a cleaner dispatch of generation units initiated by the pricing signal of the EU ETS. The dynamic development of an integrated and liberalized European electricity market, a heterogeneous endowment in generation fleets in terms of generation technology and primary fuel and business model, the fast but varied uptake of renewable energies have all co-developed in an environment of fluctuating primary fuel prices and an emerging, but for most of the time very modest, CO_2 price in the EU ETS. This report tries to shed light on this co-evolution. It provides an in-depth analysis of the electricity sector since the EU ETS was introduced in 2005. It allows key drivers behind the development in capacities, generation levels and emissions to be identified. It thereby provides key information from past developments which form the basis for future projections and the design of tailored policy instruments. The report provides information on the European level as well as for 10 selected European countries: the Czech Republic, Estonia, France, Germany, Italy, the Netherlands, Poland, Romania, Spain and the United Kingdom.

Kurzbeschreibung: Entwicklung von Feuerungsanlagen unter dem EU EHS

Die Erzeugung von Strom und Wärme ist die größte Einzelaktivität, die unter das EU-Emissionshandelssystem (EU EHS) fällt. Aufgrund der Vernetzung, der unterschiedlichen Emissionsintensität der verschiedenen Brennstoffe und ihrer Organisation in einem wettbewerbsorientierten Markt mit grenzkostenbasierter Bepreisung, verfügten die Kraftwerke über ein großes Potenzial den Kraftwerkseinsatz durch das Preissignal des EU EHS in Richtung eines „saubereren Einsatz" auszurichten. Die dynamische Entwicklung eines integrierten und liberalisierten europäischen Elektrizitätsmarktes, eine heterogene Ausstattung des Kraftwerksparks in Bezug auf die Erzeugungstechnologie, den Primärbrennstoff und das Geschäftsmodell sowie die schnelle, aber unterschiedliche Einführung erneuerbarer Energien haben sich in einem Umfeld schwankender Primärenergieträgerpreise und eines sich abzeichnenden, aber zumeist sehr geringen CO_2-Preises im EU EHS entwickelt. Der vorliegende Bericht versucht, Licht in diese Entwicklung zu bringen. Er bietet eine eingehende Analyse des Elektrizitätssektors seit der Einführung des EU EHS im Jahr 2005. Er ermöglicht es, die wichtigsten Faktoren für die Entwicklung von Kapazitäten, Erzeugungsmengen und Emissionen nachzuvollziehen. Damit liefert er Schlüsselinformationen aus der Vergangenheit, die die Grundlage für künftige Prognosen und die Gestaltung von maßgeschneiderten politischen Instrumenten bilden. Der Bericht enthält Informationen auf europäischer Ebene sowie für 10 ausgewählte europäische Länder: die Tschechische Republik, Estland, Frankreich, Deutschland, Italien, die Niederlande, Polen, Rumänien, Spanien und das Vereinigte Königreich.

Table of contents

List of figures 10
List of tables 14
List of abbreviations 16
Summary 17
Zusammenfassung........ 41
1 Introduction: Motivation and country selection 65
2 Power sector covered by the EU ETS 68
2.1 Key messages 68
2.2 Emission trends in the EU ETS (combustion installations) 69
2.3 Capacity trends 70
2.3.1 Existing capacities 70
2.3.2 Future capacity trends 75
2.4 Trends in electricity generation 77
2.5 Evolution of wholesale electricity prices, fuel, CO_2 prices 78
3 Czech Republic 81
3.1 Key messages 81
3.2 Emission trends in the EU ETS (combustion installations) 83
3.3 Capacity trends 84
3.3.1 Existing capacities 84
3.3.2 Future capacity trends 87
3.3.3 Ownership structure of coal power plants 89
3.4 Trends in electricity generation and import balance 90
3.5 Market setting 92
3.5.1 Regional market allocation and interconnectors 92
3.5.2 Electricity market design with reference to conventional power generation plants 93
4 Estonia 94
4.1 Key messages 94
4.2 Emission trends in the EU ETS (combustion installations) 96
4.3 Capacity trends 97
4.3.1 Existing capacities 97
4.3.2 Future capacity trends 98
4.3.3 Ownership structure of oil shale power plants 99
4.4 Trends in electricity generation and import balance 99

4.5 Market setting ... 102
4.5.1 Regional market allocation and interconnectors ... 102
4.5.2 Electricity market design with reference to conventional power generation plants ... 103
5 France ... 104
5.1 Key messages ... 104
5.2 Emission trends in the EU ETS (combustion installations) ... 106
5.3 Capacity trends ... 107
5.3.1 Existing capacities ... 107
5.3.2 Future capacity trends ... 111
5.3.3 Ownership structure of coal power plants ... 112
5.4 Trends in electricity generation and import balance ... 112
5.5 Market setting ... 115
5.5.1 Regional market allocation and interconnectors ... 115
5.5.2 Electricity market design with reference to conventional power generation plants ... 116
6 Germany ... 117
6.1 Key messages ... 117
6.2 Emission trends in the EU ETS (combustion installations) ... 119
6.3 Capacity trends ... 120
6.3.1 Existing capacities ... 120
6.3.2 Future capacity trends ... 124
6.3.3 Ownership structure of coal power plants ... 125
6.4 Trends in electricity generation and import balance ... 126
6.5 Market setting ... 129
6.5.1 Regional market allocation and interconnectors ... 129
6.5.2 Electricity market design with reference to conventional power generation plants ... 130
7 Italy ... 131
7.1 Key messages ... 131
7.2 Emission trends in the EU ETS (combustion installations) ... 133
7.3 Capacity trends ... 134
7.3.1 Existing capacities ... 134
7.3.2 Future capacity trends ... 137
7.3.3 Ownership structure of coal power plants ... 138
7.4 Trends in electricity generation and import balance ... 138
7.5 Market setting ... 141

7.5.1 Regional market allocation and interconnectors 141
7.5.2 Electricity market design with reference to conventional power generation plants 142
8 Netherlands 143
8.1 Key messages 143
8.2 Emission trends in the EU ETS (combustion installations) 145
8.3 Capacity trends 146
8.3.1 Existing capacities 146
8.3.2 Future capacity trends 149
8.3.3 Ownership structure of coal power plants 149
8.4 Trends in electricity generation and import balance 150
8.5 Market setting 153
8.5.1 Regional market allocation and interconnectors 153
8.5.2 Electricity market design with reference to conventional power generation plants 154
9 Poland 155
9.1 Key messages 155
9.2 Emission trends in the EU ETS (combustion installations) 157
9.3 Capacity trends 158
9.3.1 Existing capacities 158
9.3.2 Future capacity trends 162
9.3.3 Ownership structure of coal power plants 163
9.4 Trends in electricity generation and import balance 164
9.5 Market setting 167
9.5.1 Regional market allocation and interconnectors 167
9.5.2 Electricity market design with reference to conventional power generation plants 167
10 Romania 168
10.1 Key messages 168
10.2 Emission trends in the EU ETS (combustion installations) 170
10.3 Capacity trends 171
10.3.1 Existing capacities 171
10.3.2 Future capacity trends 174
10.3.3 Ownership structure of coal power plants 176
10.4 Trends in electricity generation and import balance 176
10.5 Market setting 179
10.5.1 Regional market allocation and interconnectors 179

10.5.2 Electricity market design with reference to conventional power generation plants..... 180
11 Spain 181
11.1 Key messages 181
11.2 Emission trends in the EU ETS (combustion installations) 183
11.3 Capacity trends 184
11.3.1 Existing capacities 184
11.3.2 Future capacity trends 187
11.3.3 Ownership structure of coal power plants 188
11.4 Trends in electricity generation and import balance 189
11.5 Market setting 192
11.5.1 Regional market allocation and interconnectors 192
11.5.2 Electricity market design with reference to conventional power generation plants..... 193
12 United Kingdom 194
12.1 Key messages 194
12.2 Emission trends in the EU ETS (combustion installations) 196
12.3 Capacity trends 197
12.3.1 Existing capacities 197
12.3.2 Future capacity trends 200
12.3.3 Ownership structure of coal power plants 201
12.4 Trends in electricity generation and import balance 202
12.5 Market setting 205
12.5.1 Regional market allocation and interconnectors 205
12.5.2 Electricity market design with reference to conventional power generation plants..... 206
13 References 207

List of figures

Figure 1: EU-28: Emission trends in Activity Code 20.............................19
Figure 2: Emission factor of gross electricity production in EU-28 and selected countries 20
Abbildung 1: EU-28 Emissiontrends in Activity Code 20...............................43
Abbildung 2: Emission factor der Bruttostromerzeugungfür die EU-28 und ausgewählte Länder 44
Figure 3: EU-28: Emission trends in Activity Code 20.............................69
Figure 4: Emission factor of gross electricity production in EU-28 and selected countries 70
Figure 5: Distribution of large-scale power generation units in the EU, UK, Switzerland and Norway 71
Figure 6: EU-28: Age structure of lignite and hard coal power plants sorted by year of commissioning 72
Figure 7: EU-28: New lignite and hard coal power plants since 2005, including plants under construction sorted by year of commissioning..73
Figure 8: EU-28: Retired coal-fired plant capacities in the EU-28 (including fuel switch) sorted by retirement date...................74
Figure 9: EU-28: Coal power plant capacities installed since 1950 by country including retired plants and plants under construction 75
Figure 10: EU-28: Trends of gross electricity generation and net imports77
Figure 11: Development of fuel prices, price for EU ETS emission allowances and average electricity prices in selected EU countries...79
Figure 12: Czech Republic: Emission trends in the EU ETS.......................83
Figure 13: Czech Republic: Emission trends from combustion installations in Activity Code 20..84
Figure 14: Czech Republic: Evolution of capacity trends by energy carrier 85
Figure 15: Czech Republic: Age structure of lignite and hard coal power plants sorted by year of commissioning..................................86
Figure 16: Czech Republic: Retired coal-fired plant capacities sorted by retirement date 87
Figure 17: Czech Republic: Trends of gross electricity generation and net imports 91
Figure 18: Czech Republic: Electricity generation of renewable energies 91
Figure 19: Czech Republic: Net import (positive) and net export (negative) of electricity, physical exchange with neighbouring countries 92
Figure 20: Estonia: Emission trends in the EU ETS 96
Figure 21: Estonia: Emission trends in Activity Code 20 97
Figure 22: Estonia: Evolution of capacity trends by energy carrier...........98

Figure 23: Estonia: Trends of gross electricity generation and net imports ...100
Figure 24: Estonia: Electricity generation of renewable energies...101
Figure 25: Estonia: Net import (positive) and net export (negative) of electricity, physical exchange with neighbouring countries ..102
Figure 26: France: Emission trends in the EU ETS ...106
Figure 27: France: Emission trends in Activity Code 20 ...107
Figure 28: France: Evolution of capacity trends by energy carrier...108
Figure 29: France: Age structure of hard coal power plants sorted by year of commissioning...109
Figure 30: France: Retired coal-fired plant capacities sorted by retirement date...110
Figure 31: France: Age structure of nuclear power plants sorted by year of commissioning...111
Figure 32: France: Trends of gross electricity generation and net imports ...113
Figure 33: France: Electricity generation of renewable energies...114
Figure 34: France: Net import (positive) and net export (negative) of electricity, physical exchange with neighbouring countries ..115
Figure 35: Germany: Emission trends in the EU ETS ...119
Figure 36: Germany: Emission trends in Activity Code 20 ...120
Figure 37: Germany: Evolution of gross capacity by energy carrier...121
Figure 38: Germany: Age structure of lignite and hard coal power plants sorted by year of commissioning ...122
Figure 39: Germany: New lignite and hard coal power plants since 2005 including plants under construction sorted by year of commissioning...123
Figure 40: Germany: Retired coal-fired plant capacities (including lignite plants in security standby) sorted by retirement date...124
Figure 41: Germany: Trends of gross electricity generation and net imports ...127
Figure 42: Germany: Electricity generation of renewable energies...128
Figure 43: Germany: Net import (positive) and net export (negative) of electricity, physical exchange with neighbouring countries ..129
Figure 44: Italy: Emission trends in the EU ETS ...133
Figure 45: Italy: Emission trends in Activity Code 20 ...134
Figure 46: Italy: Evolution of capacity trends by energy carrier...135
Figure 47: Italy: Age structure of hard coal power plants sorted by year of commissioning...136
Figure 48: Italy: Retired coal-fired plant capacities sorted by retirement date...137
Figure 49: Italy: Trends of gross electricity generation and net imports 139
Figure 50: Italy: Electricity generation of renewable energies...140

Figure 51: Italy: Net import (positive) and net export (negative) of electricity, physical exchange with neighbouring countries ..141
Figure 52: Netherlands: Emission trends in the EU ETS 145
Figure 53: Netherlands: Emission trends in Activity Code 20 146
Figure 54: Netherlands: Evolution of capacity trends by energy carrier.147
Figure 55: Netherlands: Age structure of hard coal power plants sorted by year of commissioning...148
Figure 56: Netherlands: Retired coal-fired plant capacities sorted by retirement date 148
Figure 57: Netherlands: Trends of gross electricity generation and net imports 151
Figure 58: Netherlands: Electricity generation of renewable energies...151
Figure 59: Netherlands: Share of biomass co-firing in total electricity from biomass...152
Figure 60: Netherlands: Net import (positive) and net export (negative) of electricity, physical exchange with neighbouring countries ..153
Figure 61: Poland: Emission trends in the EU ETS 157
Figure 62: Poland: Emission trends from combustion installations in Activity Code 20...158
Figure 63: Poland: Evolution of capacity trends by energy carrier 159
Figure 64: Poland: Age structure of lignite and hard coal power plants sorted by year of commissioning 160
Figure 65: Poland: New lignite and hard coal power plants since 2005 including plants under construction, organized by year of commissioning...161
Figure 66: Poland: Retired coal-fired plant capacities sorted by retirement date...162
Figure 67: Poland: Trends of gross electricity generation and net imports 165
Figure 68: Romania: Emission trends in the EU ETS...............................170
Figure 69: Romania: Emission trends from combustion installations in Activity Code 20..171
Figure 70: Romania: Evolution of capacity trends by energy carrier 172
Figure 71: Romania: Age structure of lignite and hard coal power plants sorted by year of commissioning 173
Figure 72: Romania: Retired coal-fired plant capacities sorted by retirement date 174
Figure 73: Romania: Trends of gross electricity generation and net imports 177
Figure 74: Romania: Electricity generation of renewable energies 178
Figure 75: Romania: Net import (positive) and net export (negative) of electricity, physical exchange with neighbouring countries ..179
Figure 76: Spain: Emission trends in the EU ETS 183

Figure 77: Spain: Emission trends from combustion installations in Activity Code 20 184
Figure 78: Spain: Evolution of capacity trends by energy carrier 185
Figure 79: Spain: Age structure of lignite and hard coal power plants sorted by year of commissioning 186
Figure 80: Spain: Retired coal-fired plant capacities sorted by retirement date 187
Figure 81: Spain: Trends of gross electricity generation and net imports 190
Figure 82: Spain: Electricity generation of renewable energies 191
Figure 83: Spain: Net import (positive) and net export (negative) of electricity, physical exchange with neighbouring countries 192
Figure 84: United Kingdom: Emission trends in the EU ETS 196
Figure 85: United Kingdom: Emission trends in Activity Code 20 197
Figure 86: United Kingdom: Evolution of capacity trends by energy carrier 198
Figure 87: United Kingdom: Age structure of hard coal power plants sorted by year of commissioning 199
Figure 88: United Kingdom: Retired coal-fired plant capacities sorted by retirement date 200
Figure 89: United Kingdom: Trends of gross electricity generation and net imports 203
Figure 90: United Kingdom: Electricity generation of renewable energies 204
Figure 91: United Kingdom: Net import (positive) and net export (negative) of electricity, physical exchange with neighbouring countries 205

List of tables

Table 1: Czech Republic: Key figures on the electricity sector in 2019..22
Table 2: Estonia: Key figures on the electricity sector in 2019 24
Table 3: France: Key figures on the electricity sector in 2019 26
Table 4: Germany: Key figures on the electricity sector in 2019 28
Table 5: Italy: Key figures on the electricity sector in 2019 30
Table 6: Netherlands: Key figures on the electricity sector in 2019 32
Table 7: Poland: Key figures on the electricity sector in 2019..............34
Table 8: Romania: Key figures on the electricity sector in 2019...........36
Table 9: Spain: Key figures on the electricity sector in 2019 38
Table 10: United Kingdom: Key figures on the electricity sector in 2019 40
Tabelle 1: Tschechische Republik: Schlüsselzahlen zum Elektrizitätssektor im Jahr 2019 46
Tabelle 2: Estland: Schlüsselzahlen zum Elektrizitätssektor im Jahr 2019 48
Tabelle 3: Frankreich: Schlüsselzahlen zum Elektrizitätssektor im Jahr 2019...50
Tabelle 4: Deutschland: Schlüsselzahlen zum Elektrizitätssektor im Jahr 2019...52
Tabelle 5: Italien: Schlüsselzahlen zum Elektrizitätssektor im Jahr 2019 .54
Tabelle 6: Niederlande: Schlüsselzahlen zum Elektrizitätssektor im Jahr 2019...56
Tabelle 7: Polen: Schlüsselzahlen zum Elektrizitätssektor im Jahr 2019 ..58
Tabelle 8: Rumänien: Schlüsselzahlen zum Elektrizitätssektor im Jahr 2019...60
Tabelle 9: Spanien: Schlüsselzahlen zum Elektrizitätssektor im Jahr 2019 62
Tabelle 10: Vereinigtes Königreich: Schlüsselzahlen zum Elektrizitätssektor im Jahr 2019 64
Table 11 Overview of emissions and electricity generation of European countries...66
Table 12: Overview of coal phase-out and RES–targets for 10 selected countries...76
Table 13: Czech Republic: Key figures on the electricity sector in 2019..82
Table 14: Czech Republic: Ownership structure of the coal-fired electricity generation fleet 89
Table 15: Czech Republic: Net transfer capacity with neighbouring countries in 2018 (MW)..93
Table 16 Estonia: Key figures on the electricity sector in 2019 95
Table 17: Estonia: Maximum forecasted transfer capacity with neighbouring countries in 2021 (MW) 103
Table 18 France: Key figures on the electricity sector in 2019 105
Table 19: France: Ownership structure of the coal-fired electricity generation fleet 112

Table 20: France: Maximum forecasted transfer capacity with neighbouring countries in 2021 (MW) 115
Table 21: Germany: Key figures on the electricity sector in 2019 118
Table 22: Germany: Ownership structure of the coal-fired electricity generation fleet 125
Table 23: Germany: Maximum transfer capacity with neighbouring countries in 2020 (MW)...130
Table 24 Italy: Key figures on the electricity sector in 2019 132
Table 25: Italy: Ownership structure of the coal-fired electricity generation fleet 138
Table 26: Italy: Maximum forecasted transfer capacity with neighbouring countries in 2021 (MW)...142
Table 27 Netherlands: Key figures on the electricity sector in 2019 144
Table 28: Netherlands: Ownership structure of the coal-fired electricity generation fleet 150
Table 29: Netherlands: Maximum forecasted transfer capacity with neighbouring countries in 2021 (MW) 154
Table 30: Poland: Key figures on the electricity sector in 2019.............156
Table 31: Poland: Ownership structure of the coal-fired electricity generation fleet 164
Table 32: Poland: Net import balance with neighbouring countries (actual, physical flows) 166
Table 33: Poland: Net transfer capacity with neighbouring countries in 2018 (MW)...167
Table 34 Romania: Key figures on the electricity sector in 2019..........169
Table 35: Romania: Ownership structure of the coal-fired electricity generation fleet 176
Table 36: Romania: Maximum forecasted transfer capacity with neighbouring countries in 2021 (MW) 179
Table 37 Spain: Key figures on the electricity sector in 2019 182
Table 38: Spain: Ownership structure of the coal-fired electricity generation fleet 189
Table 39: Spain: Maximum forecasted transfer capacity with neighbouring countries in 2021 (MW) 192
Table 40 United Kingdom: Key figures on the electricity sector in 2019 195
Table 41: United Kingdom: Ownership structure of the coal-fired electricity generation fleet 201
Table 42: United Kingdom: Maximum forecasted transfer capacity with neighbouring countries in 2021 (MW) 206

List of abbreviations

CHP	Combined Heat and Power
CO_2	Carbon dioxide
EED	Energy Efficiency Directive
ENTSO-E	European association for the cooperation of transmission system operators (TSOs) for electricity
ERDF	European Regional Development Fund
EU ETS	EU Emissions Trading System
EUTL	EU Transaction Log (EU ETS registry)
GW	Gigawatt
MW	Megawatt
MWh	Megawatt hour
NECP	National Energy and Climate Plan
NEMO	Nominated Electricity Market Operator
PV	Photovoltaic
RES	Renewable Energy Sources
TSO	Transmission System Operator

Summary

The generation of electricity and heat is the largest single activity covered by the EU Emissions Trading System (EU ETS). Combustion installations summarized under Activity Code 20 comprised 63 % of total emissions covered by the EU ETS in 2019. According to our research, more than 81 % of these installations are electric or combined heat and power plants. Due to the interconnectedness, the difference in emission intensity of the different fuels and their configuration in a competitive marginal cost pricing market, installations under Activity Code 20 also had a large potential for a cleaner dispatch of generation units initiated by the pricing signal of the EU ETS.

The dynamic development of an integrated and liberalized European electricity market, a heterogeneous endowment in generation fleets in terms of generation technology and primary fuel and business model, the fast but diversified uptake of renewable energies, have all co-developed in an environment of fluctuating primary fuel prices and an emerging, but for most of the time very modest CO_2 price in the EU ETS. This report tries to shed light into this co-evolution.

It provides an in-depth analysis of the electricity sector in the period from 2005 to 2019. i.e., before the end of the 3rd ETS trading period in 2020 and before the significant changes of economic activity that have been associated with the COVID pandemic. Likewise, changes in the macroeconomic framework since then are not covered, and also potential impacts of the “fit-for-55” framework that was casted in law in 2023. Among other things, this reform package foresees changes in the ETS cap path and the introduction of a “carbon border adjustment mechanism” (CBAM), which is to gradually replace free allocations for industrial sectors including the iron and steel industry. Furthermore, allowance prices have risen substantially since 2018 and continued to do so also after 2019 (see e.g. DEHSt (2024) for a graphical illustration of the observed price developments), which can be attributed at least in part to a growing perception of scarcity in the market.

Our analysis allows key drivers behind the development in capacities, generation levels and emissions to be identified. It thereby provides key information from past developments which form the basis for future projections and the design of tailored policy instruments.

The report provides information on the European level as well as for 10 selected European countries in the form of brief fact sheets. In order to provide a broad picture of national trends in the EU, the following countries were chosen for fact sheets: the Czech Republic, Estonia, France, Germany, Italy, the Netherlands, Poland, Romania, Spain and the United Kingdom.

Emissions connected with the Activity Code 20 (combustion installations) have declined sharply in recent years in the countries covered by the EU ETS. Figure 4 shows the development of emission factors for the EU-28 and for the ten countries selected for this study in direct comparison between 2010 and 2019. Estonia, Poland, the Czech Republic, Germany, the Netherlands and Romania had more emission-intensive electricity generation than the EU-28 average throughout the period. The trend of Italy's emission factors is quite similar to that of the EU-28, while the UK changed from having higher emission factors than the EU average until 2014 to lower emission factors from 2015 onwards. The emission factors of Spain and France were always below the EU-28 values in the period considered. The following chapters examine more closely the reasons for these very different emission factor levels.

Figure 1 shows the emission trends of combustion installations in the EU-28 between 2010 and 2019 based on EUTL data (EC n.d.) and our own research. Power plants are differentiated by fuel in the figure.

Lignite and hard coal-fired power plants accounted for about 65 % of all emissions covered by Activity Code 20 in 2013. This percentage decreased to 47 % in 2019. Emissions from lignite power plants amounted to approx. 260 Mt in 2019, corresponding to a reduction of 27 % compared to 2013. Emissions from hard coal power plants amounted to 200 Mt CO_2 in 2019, corresponding to a reduction of 59 % compared to 2013. During the same period, emissions from blast furnace power plants remained unchanged at 53 Mt CO_2. Emissions from the category “Other Combustion (Activity Code 20; Power Marker),” which are natural gas-fired, oil-fired and other power plants saw only a 3 % increase from 252 Mt CO_2 in 2013 to 260 Mt CO_2 in 2019.

However, the strongest decline occurred between 2018 and 2019: within one year, emissions from power plants decreased by 142 Mt CO_2. Hard coal power plants mostly contributed to this abatement (91 Mt CO_2 from hard coal power plants). Lignite-fired power plants contributed 57 Mt CO_2. Emissions from other power plants (mainly natural gas-fired) increased by about 10 Mt CO_2 from 2018 to 2019.

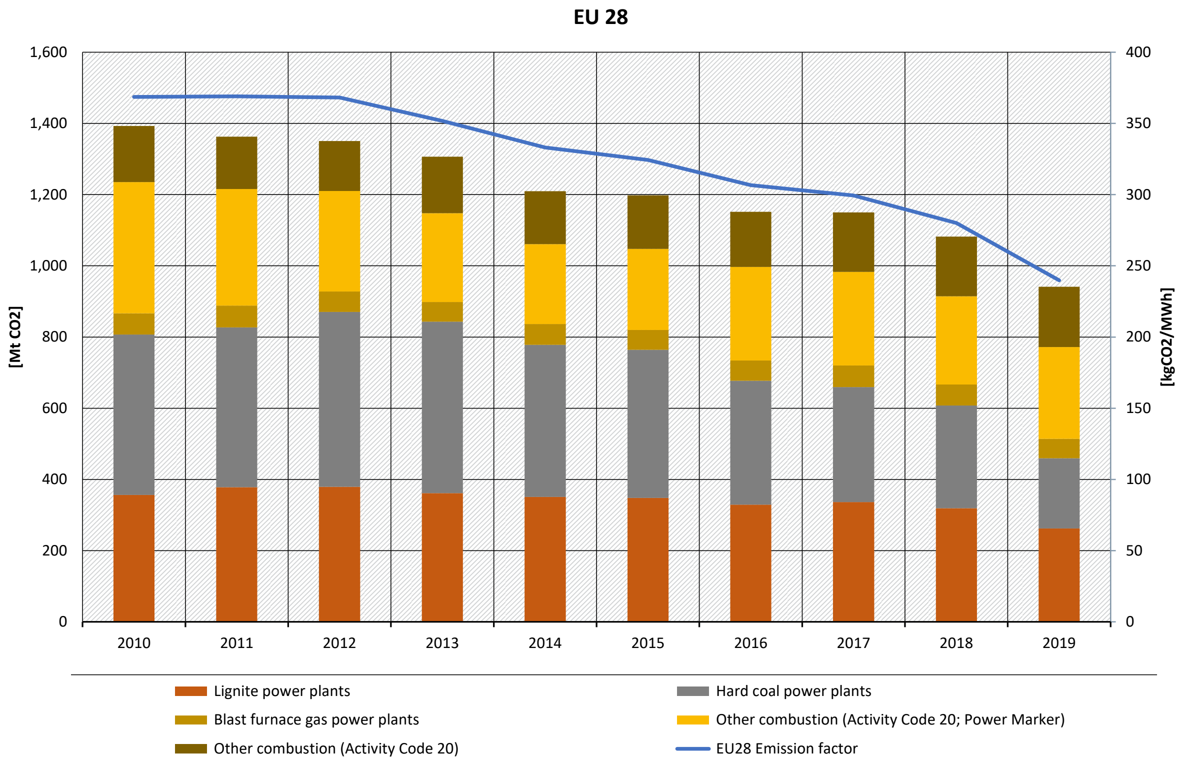
The category "Other combustion (Activity Code 20)” includes the non-electricity generating installations and remained stable between 2010 and 2019.

Figure 1 also includes the emission factor of gross electricity production in the EU-28. It declined from 370 kg CO_2/MWh in 2010 to 240 kg CO_2/MWh in 2019.

The declining trends also continued in 2020, driven by continued decline in coal-fired electricity generation due to high prices in the EU ETS, but also due to reduced demand during the COVID pandemic. In 2021 and 2022, the start of the fourth trading period, emissions initially increased, again. This was due to higher demand for electricity as a result of the economic recovery following the COVID pandemic, as well as a switch in relative costs of coal-fired versus gas-fired generation as a consequence of the Russian war of aggression against Ukraine. This short-lived trend in coal-fired power generation reversed in 2023. As a result, emissions from power generation fell significantly, and reached their lowest level since the start of the EU ETS in 2005. This is mainly due to the sharp drop in energy demand from industry and households driven by sharply increased energy prices.

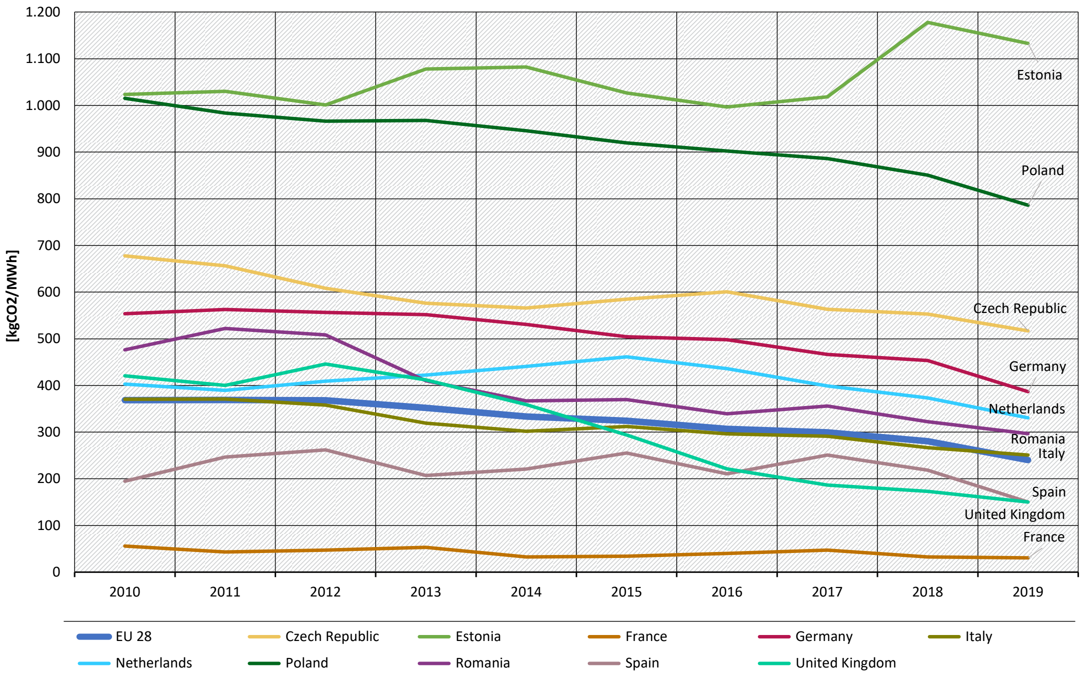
Figure 2 shows the development of emission factors for the EU-28 and for the ten countries selected for this study in direct comparison between 2010 and 2019. Estonia, Poland, the Czech Republic, Germany, the Netherlands and Romania had more emission-intensive electricity generation than the EU-28 average throughout the period. The trend of Italy’s emission factors is quite similar to that of the EU-28, while the UK changed from higher emission factors than the EU average up to 2014 to lower emission factors from 2015 onwards. The emission factors of Spain and France were always below the EU-28 values in the period considered. The following chapters examine more closely the reasons for these very different emission factor levels.

Figure 1: EU-28: Emission trends in Activity Code 20



Note: Data for Croatia were extrapolated for the years 2010-2012 using total GHG inventory data as a proxy for emission trends. Emissions in the category: other combustion (Activity Code 20; Power Marker) are calculated using the deduction method: All emissions with Power Marker minus emissions from lignite and hard coal-fired power plants minus emissions from blast furnace gas power plants.
Source: Own illustration based on data from Europe Beyond Coal (2022), EEA (2022), Ember (2020), and own assignment based on EC n.d..

Figure 2: Emission factor of gross electricity production in EU-28 and selected countries



Note: Emission factor calculated based on CO_2 emissions by power plants identified in Oeko-Institut's EU ETS database and gross electricity production reported by Ember (2020). It might differ from the values given under EEA (2022).
Source: Own illustration based on data from Ember (2020), and own assignment based on EC n.d. for individual countries and Europe Beyond Coal (2022), EEA (2022) for EU-28.

In the following pages, the key messages of the country profiles are provided.

Czech Republic

- In 2019, combustion installations (Activity Code 20) in the Czech Republic emitted 49 Mt CO_2, which made Czech Republic the 7th largest emitter (5 %) in this category. Electricity producers account for 90 % of emissions under this category. Between 2013 and 2019, emissions from electricity generators decreased by 11 % only (which is similar to the Netherlands; electricity-related emissions fell more sharply in all other Member States analysed).
- The generation mix is dominated by lignite-fired generation (41 %). Hard coal has a small share of only 2 %. While the latter declined by 75 % between 2013 and 2019, the former decreased by 1 % only. Over 80 % of the coal-fired generation fleet was installed before 1990. Nuclear is the second pillar of electricity generation, contributing about one third of total generation. Gas-fired capacity has increased to 2 GW since 2013 but increased its share in generation only when CO_2 prices went up in 2018 and 2019.
- Electricity supply from renewables had a low share of 13 % in 2019 and has not shown a strong dynamic in recent years.
- The Czech Republic is a net exporter of electricity in the Central European electricity system. Due to its location in the system, it also provides transit capacity for generation from Northern Germany to Southern Germany in times of high wind generation in the North (loop flows). These loop flows have declined in recent years with increasing demand in Poland and the installation of phase shifters.
- Coal-fired generation is dominated by state-owned ČEZ company (60 % of coal-fired generation in 2019). A coal phase-out by 2038 was recommended by a national coal commission convened by the government in December 2020. In January 2022, the new centre-right Czech government, elected in October 2021, announced its intention to phase out coal by 2033; the plans had not been cast in law by the time this report was completed.

Table 1: Czech Republic: Key figures on the electricity sector in 2019

	2019	% change compared to 2013
	CO_2 emissions	
Total CO_2 emissions in 2019 from ETS Activity Code 20 (share of EU-28)	49 Mt CO_2 (5%)	-11%
Total CO_2 emissions from electricity producers[1] (share of Activity Code 20in the country)	45 Mt CO_2 (90%)	-11%
Emission factor of gross electricity production[2] (relative to EU-28 average)	0.52 t CO_2/MWh (216%)	-10%
	Gross electricity generation	
Total (share of total EU-28)	86 TWh (3%)	0%
Net electricity imports	-13 TWh	-26%
Lignite share in gross generation (share of total gross lignite-fired generation in EU-28)	41% (14%)	-1%
Hard coal share in gross generation (share of total gross hard coal-fired generation in EU-28)	2% (1%)	-75%
RES share in gross generation (target for 2030)[3]	13% (17%)	10%
	Installed capacity	
Total lignite-fired capacity installed (share of total EU-28)	7.8 GW (15%)	-4%
Share of lignite-fired capacity installed before 1990 (share of total EU-28)	81% (13%)	-5%
Total hard coal-fired capacity installed (share of total EU-28)	1.4 GW (1%)	-3%
Share of hard coal-fired capacity installed before 1990 (share of total EU-28)	85% (2%)	-6%

Note: [1] CO_2 emissions from electricity producers based on power plants identified in Oeko-Institut's EU ETS database.
[2] Emission factor calculated based on CO_2 emissions by power plants identified in Oeko-Institut's EU ETS database and gross electricity production reported by Ember (2020).
[3] According to Article 4 (2) Regulation (EU) 2018/1999, MSs have to provide information on their contribution to the Union's binding renewable energy target of at least 32% expressed as renewable energy share on gross final energy consumption. They do so in their NECPs (Article 3(2)(b)). Along with this contribution they also have to report on *estimated trajectories for the sectoral share of renewable energy in final energy consumption from 2021 to 2030 in the electricity, heating and cooling, and transport sector* (see Annex I Regulation (EU) 2018/1999 which sets out the structure of the NECPs)
Source: Own table based on Ember (2020), EC n.d., Europe Beyond Coal (2022), and EEA (2021).

Estonia

- In 2019, combustion installations (Activity Code 20) in Estonia emitted 6 Mt CO_2, which made Estonia the 22nd largest emitter (1 %) in this category. Electricity producers account for 96 % of emissions under this category. Between 2013 and 2019, emissions from electricity generators decreased by 57 %.
- The generation mix is dominated by oil shale-fired generation which accounted for more than 85 % of total production between 2005 and 2018. With an increasing CO_2 price, the share has dropped below 80 % in 2019.
- Estonia is increasingly integrated with neighbouring countries. The country's position in the Nord Pool electricity market is highly reactive to CO_2 price signals. With increasing CO_2 prices, the country has changed from a net exporter of electricity, exporting 20 % or more of its generation in the years before 2019, to a net importer, supplying almost 30 % of consumption by imports in 2019.
- Due to the pivotal role of oil shale in electricity generation, the average emission factor of gross electricity generation is about 1.0 Mt CO_2 per MWh, which is more than four times higher than the EU-28 average emission factor in 2019.
- Energy supply from renewable sources plays an increasing role and comprised 22 % of total gross generation in 2019, an increase of about 140 % compared to 2013.
- The new Estonian coalition plans to cease power generation from oil shale by 2035, and to achieve a 40 % RES share in electricity generation by 2030. It plans to do so mainly by expanding wind generation but has also installed a working group to assess the prospects of introducing nuclear power generation in Estonia.

Table 2: Estonia: Key figures on the electricity sector in 2019

	2019	% change compared to2013
	CO_2 emissions	
Total CO_2 emissions in 2019 from ETS Activity Code 20 (share of EU-28)	6 Mt CO_2 (1%)	-56%
Total CO_2 emissions from electricity producers[1] (share of Activity Code 20in the country)	6 Mt CO_2 (96%)	-57%
Emission factor of gross electricity production[2] (relative to EU-28 average)	0.99 t CO_2/MWh (414%)	-5%
	Gross electricity generation	
Total (share of total EU-28)	6 TWh (0%)	-55%
Net electricity imports	2 TWh	-162%
Lignite share in gross generation (share of total gross lignite-fired generation in EU-28)	0% (0%)	0%
Hard coal share in gross generation (share of total gross hard coal-fired generation in EU-28)	0% (0%)	0%
RES share in gross generation (target for 2030)[3]	22% (40%)	138%
	Installed capacity	
Total lignite-fired capacity installed (share of total EU-28)	0	
Share of lignite-fired capacity installed before 1990 (share of total EU-28)	0	
Total hard coal-fired capacity installed (share of total EU-28)	0	
Share of hard coal-fired capacity installed before 1990 (share of total EU-28)	0	

Note: [1] CO_2 emissions from electricity producers based on power plants identified in Oeko-Institut's EU ETS database.
[2] Emission factor calculated based on $_{CO2}$ emissions by power plants identified in Oeko-Institut's EU ETS database and gross electricity production reported by Ember (2020).
[3] According to Article 4 (2) Regulation (EU) 2018/1999, MSs have to provide information on their contribution to the Union's binding renewable energy target of at least 32% expressed as renewable energy share on gross final energy consumption. They do so in their NECPs (Article 3(2)(b)). Along with this contribution they also have to report on *estimated trajectories for the sectoral share of renewable energy in final energy consumption from 2021 to 2030 in the electricity, heating and cooling, and transport sector* (see Annex I Regulation (EU) 2018/1999 which sets out the structure of the NECPs)
Source: Own table based on Ember (2020), EC n.d., Europe Beyond Coal (2022), and EEA (2021).

France

- In 2019, combustion installations (Activity Code 20) in France emitted 43 Mt CO_2, which made France the 8th largest emitter (5 %) in this category. Electricity producers account for only 41 % of emissions under this category; this is much lower than in the other analysed Member States, for which the share of electricity is around 75 % or higher (another exception is the UK). Between 2013 and 2019, emissions from electricity generators decreased by 43 %.
- Coal-fired generation decreased in two waves: one in 2013 to 2015, when a combination of air pollution regulations and the start of auctioning of EU ETS allowances for electricity generation instead of free allocation made the continued operation of these power plants financially less attractive; and one in 2018 and 2019 when higher CO_2 prices induced a fuel switch from coal to gas.
- France is a major exporter of electricity in the Central European electricity system, with 50 TWh of exports on average between 2005 and 2019. Electricity is exported in particular to the United Kingdom and Italy. To a smaller extent, electricity is also exported to Germany and Spain.
- A coal phase-out is planned for 2027, later than originally envisaged. The nuclear fleet will require substantial re-investments in the years ahead; 30 % of the installations are older than 40 years and 88 % are at least 30 years old or more.
- In 2017, France introduced a capacity market, in which suppliers are obliged to hold sufficient capacity guarantee certificates that can be traded. Due to the threshold level of 200g CO_2/MWh, gas-fired generation is excluded, and capacity provision comes mostly from nuclear and hydro power plants.

Table 3: France: Key figures on the electricity sector in 2019

	2019	% change compared to 2013
	CO_2 emissions	
Total CO_2 emissions in 2019 from ETS Activity Code 20 (share of EU-28)	43 Mt CO_2 (5%)	-26%
Total CO_2 emissions from electricity producers[1] (share of Activity Code 20in the country)	17 Mt CO_2 (41%)	-43%
Emission factor of gross electricity production[2] (relative to EU-28 average)	0.03 t CO_2/MWh (13%)	-42%
	Gross electricity generation	
Total (share of total EU-28)	570 TWh (18%)	-2%
Net electricity imports	-61 TWh	26%
Lignite share in gross generation (share of total gross lignite-fired generation in EU-28)	0% (0%)	0%
Hard coal share in gross generation (share of total gross hard coal-fired generation in EU-28)	1% (2%)	-83%
RES share in gross generation (target for 2030)[3]	21% (40%)	15%
	Installed capacity	
Total lignite-fired capacity installed (share of total EU-28)	0 GW (0%)	0%
Share of lignite-fired capacity installed before 1990 (share of total EU-28)	0%	0%
Total hard coal-fired capacity installed (share of total EU-28)	3.2 GW (3%)	-56%
Share of hard coal-fired capacity installed before 1990 (share of total EU-28)	100% (6%)	0%

Note: [1] CO_2 emissions from electricity producers based on power plants identified in Oeko-Institut's EU ETS database.
[2] Emission factor calculated based on CO_2 emissions by power plants identified in Oeko-Institut's EU ETS database and gross electricity production reported by Ember (2020).
[3] According to Article 4 (2) Regulation (EU) 2018/1999, MSs have to provide information on their contribution to the Union's binding renewable energy target of at least 32% expressed as renewable energy share on gross final energy consumption. They do so in their NECPs (Article 3(2)(b)). Along with this contribution they also have to report on *estimated trajectories for the sectoral share of renewable energy in final energy consumption from 2021 to 2030 in the electricity, heating and cooling, and transport sector* (see Annex I Regulation (EU) 2018/1999 which sets out the structure of the NECPs)
Source: Own table based on Ember (2020), EC n.d., Europe Beyond Coal (2022), and EEA (2021).

Germany

- In 2019, combustion installations (Activity Code 20) in Germany emitted 245 Mt $_{CO2}$, which made Germany the largest emitter (26 %) in this category. Electricity producers account for 95 % of emissions under this category. Between 2013 and 2019, emissions from electricity generators decreased by 33 %.
- By 2019, Germany has a diverse generation mix. The shares of lignite- and hard coal-fired generation are 19 % and 9 % respectively. Between 2013 and 2019, hard coal-fired generation declined by 55 % while lignite-fired generation decreased by 29 %. More than 55 % of the coal-fired generation fleet was installed before 1990. Gas-fired generation had a share of 15 % in 2019, which corresponds to a 35 % increase since 2013. Nuclear generation decreased its share substantially between 2005 and 2019, from 26 % to 12 %. In particular in 2018 and even more so in 2019, coal-fired generation was compensated by an increasing gas-fired and wind generation, and a reduction in exports. Assessments of the fuel switch potential show that between the end of 2018 and mid- 2021, marginal generation costs of natural gas-fired power plants where below those of hard coal-fired ones.
- Electricity supply from renewables has a share of 40 % in 2019 and increased by 66 % between 2013 and 2019. The plan to increase this share to 80 % by 2030 builds on a strong expansion of wind and solar PV capacities. Biomass-based generation increased up to 2015 and has been stable since then.
- Due to the prominent role of coal in electricity generation in Germany, the average emission factor of gross electricity generation is about 0.4 Mt $_{CO2}$ per MWh, which is 60 % higher than the EU-28 average emission factor in 2019.
- Germany is a net exporter of electricity in the Central European electricity system and is well integrated with its neighbouring countries. Internal grid bottlenecks between the North and the South are not reflected in the market design and have led to loop flows in Poland and the Czech Republic.
- A coal phase-out is enacted by the end of 2038, with defined intermediate steps in 2022 and 2030. Nuclear was phased-out in April 2023.

Table 4: Germany: Key figures on the electricity sector in 2019

	2019	% change compared to 2013
	CO_2 emissions	
Total CO_2 emissions in 2019 from ETS Activity Code 20 (share of EU-28)	245 Mt CO_2 (26%)	-32%
Total CO_2 emissions from electricity producers[1] (share of Activity Code 20in the country)	234 Mt CO_2 (95%)	-33%
Emission factor of gross electricity production[2] (relative to EU-28 average)	0.39 t CO_2/MWh (161%)	-30%
	Gross electricity generation	
Total (share of total EU-28)	605 TWh (19%)	-4%
Net electricity imports	-37 TWh	14%
Lignite share in gross generation (share of total gross lignite-fired generation in EU-28)	19% (45%)	-29%
Hard coal share in gross generation (share of total gross hard coal-fired generation in EU-28)	9% (26%)	-55%
RES share in gross generation (target for 2030)[3]	40% (80%)	66%
	Installed capacity	
Total lignite-fired capacity installed (share of total EU-28)	22.1 GW (40%)	-2%
Share of lignite-fired capacity installed before 1990 (share of total EU-28)	56% (25%)	-14%
Total hard coal-fired capacity installed (share of total EU-28)	25.4 GW (26%)	-12%
Share of hard coal-fired capacity installed before 1990 (share of total EU-28)	57% (27%)	- 18%

Note: Note: [1] CO_2 emissions from electricity producers based on power plants identified in Oeko-Institut's EU ETS database. [2] Emission factor calculated based on CO_2 emissions by power plants identified in Oeko-Institut's EU ETS database and gross electricity production reported by Ember (2020). [3] According to Article 4 (2) Regulation (EU) 2018/1999, MSs have to provide information on their contribution to the Union's binding renewable energy target of at least 32% expressed as renewable energy share on gross final energy consumption. They do so in their NECPs (Article 3(2)(b)). Along with this contribution they also have to report on *estimated trajectories for the sectoral share of renewable energy in final energy consumption from 2021 to 2030 in the electricity, heating and cooling, and transport sector* (see Annex I Regulation (EU) 2018/1999 which sets out the structure of the NECPs).

Source: Own table based on EC n.d., Europe Beyond Coal (2022), Ember (2020), and EEA (2021).

Italy

- In 2019, combustion installations (Activity Code 20) in Italy emitted 83 Mt $_{CO2}$, which made Italy the 3rd largest emitter (9 %) in this category. Electricity producers account for 87 % of emissions under this category. Between 2013 and 2019, emissions from electricity generators decreased by 21 %.
- The generation mix is dominated by gas-fired generation, which accounts for about 50 % of gross electricity production in 2019. Hard coal contributed a share of 6 % in 2019, while in 2013 generation amounted to 45 TWh or was 60 % higher. Only one third of the coal-fired generation fleet was installed before 1990. The share of other fossil fuels (such as waste gases from refineries and steelmaking) has strongly declined since 2005 and comprised only 5 % in total generation in 2019.
- The emission factor of gross electricity production of 0.25 t CO_2 per MWh is at a similar level as the value for the EU-28. With decreasing generation by coal and other fossil fuels, it has decreased by more than 20 % since 2013.
- Electricity supply from renewables comprised 40 % of total generation in 2019. Hydro power is a traditional renewable energy source in Italy, generating 40 to 60 TWh and contributing 40 % of the renewable electricity share in 2019. Biomass, wind and solar were expanding rapidly in the period up to 2014 and then stagnated until 2018; installations increased again only in 2019.
- Italy is a major importer of electricity in the Central European electricity system, with 43 TWh of imports on average between 2005 and 2019. Correspondingly, electricity prices set by gas-fired generation and imports are high compared to nuclear or coal-based generation in France or Germany, the main origins of the imports (with Germany also supplying via Switzerland and Austria).
- A coal phase-out planned for 2025 is linked to the construction of new gas-fired capacities, which are planned to be procured through auctions. Due to delays in the expansion of Sardinia's connection to the mainland, the coal-fired power plant there will continue to operate until 2027.

Table 5: Italy: Key figures on the electricity sector in 2019

	2019	% change compared to 2013
	CO_2 emissions	
Total CO_2 emissions in 2019 from ETS Activity Code 20 (share of EU-28)	83 Mt CO_2 (9%)	-18%
Total CO_2 emissions from electricity producers[1] (share of Activity Code 20in the country)	72 Mt CO_2 (87%)	-21%
Emission factor of gross electricity production[2] (relative to EU-28 average)	0.25 t CO_2/MWh (104%)	-21%
	Gross electricity generation	
Total (share of total EU-28)	289 TWh (9%)	0%
Net electricity imports	41 TWh	-4%
Lignite share in gross generation (share of total gross lignite-fired generation in EU-28)	0% (0%)	0%
Hard coal share in gross generation (share of total gross hard coal-fired generation in EU-28)	6% (8%)	-59%
RES share in gross generation (target for 2030)[3]	40% (55%)	2%
	Installed capacity	
Total lignite-fired capacity installed (share of total EU-28)	0 GW (0%)	0%
Share of lignite-fired capacity installed before 1990 (share of total EU-28)	0%	0%
Total hard coal-fired capacity installed (share of total EU-28)	8.6 GW (9%)	-11%
Share of hard coal-fired capacity installed before 1990 (share of total EU-28)	34% (5%)	-19%

Note: [1] CO_2 emissions from electricity producers based on power plants identified in Oeko-Institut's EU ETS database.
[2] Emission factor calculated based on CO_2 emissions by power plants identified in Oeko-Institut's EU ETS database and gross electricity production reported by Ember (2020).
[3] According to Article 4 (2) Regulation (EU) 2018/1999, MSs have to provide information on their contribution to the Union's binding renewable energy target of at least 32% expressed as renewable energy share on gross final energy consumption. They do so in their NECPs (Article 3(2)(b)). Along with this contribution they also have to report on *estimated trajectories for the sectoral share of renewable energy in final energy consumption from 2021 to 2030 in the electricity, heating and cooling, and transport sector* (see Annex I Regulation (EU) 2018/1999 which sets out the structure of the NECPs)
Source: Own table based on Ember (2020), EC n.d., Europe Beyond Coal (2022), and EEA (2021).

Netherlands

- In 2019, combustion installations (Activity Code 20) in the Netherlands emitted 54 Mt $_{CO2}$, which made the Netherlands the 6th largest emitter (6 %) in this category. Electricity producers account for 74 % of emissions under this category. Between 2013 and 2019, emissions from electricity generators decreased by 11 % only (which is similar to the Czech Republic; electricity-related emissions fell more sharply in all other Member States analysed).
- Due to domestic gas reserves, the generation mix is dominated by gas-fired generation which accounts for about 50 % to 60 % of gross electricity production between 2005 and 2019. Earthquakes followed by public protests led to the decision to reduce production at the Groningen Field in 2018; however, supply to domestic electricity producers was unaffected. On average, hard coal contributed a share of 24 % between 2005 and 2019. However, with the installation of three new blocks in 2015 and one in 2016 and a net capacity increase of 0.7 GW, the share increased, peaking at 36 % in 2015. The entire coal-fired generation fleet was installed after 1990. In the Netherlands, the co-firing of biomass in hard coal-fired power plants has been subsidised in the past and is still practised but is no longer part of the support scheme for new plants. A small nuclear reactor provides a constant share of 3 % to 4 % of gross production.
- The emission factor of gross electricity production, 0.33 t CO_2 per MWh, is one third higher than the value for the EU-28 in 2019. While the levels were similar in 2010, the EU-28 emission factor decreased steadily while the Dutch emission factor rose with increasing coal-fired generation in the Netherlands in the years 2011 to 2013. Between 2013 and 2019, the Dutch emission factor decreased by 22 % only.
- Electricity supply from renewables comprised only 18 % of total generation in 2019. Wind and solar have expanded rapidly since 2013, while biomass, the third largest RES-E source in the Netherlands, did not show a similar dynamic. Nevertheless, the Dutch NECP expects a 73 % share of renewables in electricity production by 2030, which is planned to come from strong additions in offshore wind, but also onshore wind and solar PV.
- The Netherlands is an important transit country for electricity from Germany and Norway to the UK. At the same time, the country was a net importer of electricity for most of the years in the period assessed. The extent of net imports was governed by excess generation from Germany.
- A coal phase-out plan is in place which foresees the shutdown of the last plant by the end of 2029. The Netherlands have also introduced a carbon floor price for electricity generation, starting at 12.30 Euro in 2020 and progressively increasing to 31.90 Euro by 2030.

Table 6: Netherlands: Key figures on the electricity sector in 2019

	2019	% change compared to 2013
	CO_2 emissions	
Total CO_2 emissions in 2019 from ETS Activity Code 20 (share of EU-28)	54Mt CO_2 (6%)	-7%
Total CO_2 emissions from electricity producers[1] (share of Activity Code 20in the country)	40 Mt $_{CO2}$ (74%)	-7%
Emission factor of gross electricity production[2] (relative to EU-28 average)	0.33 t CO_2/MWh (138%)	-22%
	Gross electricity generation	
Total (share of total EU-28)	121 TWh (4%)	19%
Net electricity imports	0 TWh	-98%
Lignite share in gross generation (share of total gross lignite-fired generation in EU-28)	0% (0%)	0%
Hard coal share in gross generation (share of total gross hard coal-fired generation in EU-28)	14% (8%)	-33%
RES share in gross generation (target for 2030)[3]	18% (73%)	48%
	Installed capacity	
Total lignite-fired capacity installed (share of total EU-28)	0 GW (0%)	0%
Share of lignite-fired capacity installed before 1990 (share of total EU-28)	0%	0%
Total hard coal-fired capacity installed (share of total EU-28)	5 GW (5%)	16%
Share of hard coal-fired capacity installed before 1990 (share of total EU-28)	0% (0%)	-100%

Note: [1] CO_2 emissions from electricity producers based on power plants identified in Oeko-Institut's EU ETS database.
[2] Emission factor calculated based on CO_2 emissions by power plants identified in Oeko-Institut's EU ETS database and gross electricity production reported by Ember (2020).
[3] According to Article 4 (2) Regulation (EU) 2018/1999, MSs have to provide information on their contribution to the Union's binding renewable energy target of at least 32% expressed as renewable energy share on gross final energy consumption. They do so in their NECPs (Article 3(2)(b)). Along with this contribution they also have to report on *estimated trajectories for the sectoral share of renewable energy in final energy consumption from 2021 to 2030 in the electricity, heating and cooling, and transport sector* (see Annex I Regulation (EU) 2018/1999 which sets out the structure of the NECPs)
Source: Own table based on Ember (2020), EC n.d., Europe Beyond Coal (2022), and EEA (2021).

Poland

- In 2019, combustion installations (Activity Code 20) in Poland emitted 145 Mt $_{CO2}$, which made Poland the 2nd largest emitter (15 %) in this category. Electricity producers account for 87 % of emissions under this category. Between 2013 and 2019, emissions from electricity generators decreased by 20 %.
- Comparing generation with the EU-28, Poland has the highest share of coal in the generation mix. The mix is dominated by hard coal-fired generation (48 %). Lignite-fired generation adds another 26 %. Between 2013 and 2019, lignite-fired generation declined by 24 %, while hard coal-fired generation decreased by only 6 %. A substantial reduction of coal power generation can be seen predominantly in 2019 when it was substituted by increased generation from natural gas and imports from abroad. Over two thirds of the coal-fired generation fleet was installed before 1990. Gas-fired capacity has increased to 1.8 GW since 2015; its share in generation increased especially when CO_2 prices rose in 2018 and 2019.
- Electricity supply from renewables had a low share of 15 % in 2019, though it increased by 43 % between 2013 and 2019. The plan to increase this share to 32 % by 2030 builds on a strong expansion of offshore wind capacities in the Baltic Sea.
- Due to the pivotal role of coal in electricity generation, the average emission factor of gross electricity generation is about 0.8 Mt CO_2 per MWh, which is more than three times higher than EU-28average emission factor of the EU-28 in 2019.
- Poland changed from being a net exporter of electricity in the Central European electricity system to being an importer. Due to its location in the system, it also provides transit capacity for generation from northern Germany to southern Germany in times of high wind generation in the north (loop flows). These loop flows have declined in recent years with decreasing domestic production in Poland.
- Coal-fired generation is dominated by companies in which the Polish government is the majority shareholder. A coal phase-out is planned by 2049, but only applies to hard coal mining. Poland has frequently announced a plan to construct nuclear power plants, though no concrete plans have materialized yet.

Table 7: Poland: Key figures on the electricity sector in 2019

	2019	% change compared to 2013
	CO_2 emissions	
Total CO_2 emissions in 2019 from ETS Activity Code 20 (share of EU-28)	145 Mt CO_2 (15%)	-15%
Total CO_2 emissions from electricity producers[1] (share of Activity Code 20in the country)	127 Mt CO_2 (88%)	-20%
Emission factor of gross electricity production[2] (relative to EU-28 average)	0.79 t CO_2/MWh (328%)	-19%
	Gross electricity generation	
Total (share of total EU-28)	161 TWh (5%)	-1%
Net electricity imports	10 TWh	-323%
Lignite share in gross generation (share of total gross lignite-fired generation in EU-28)	26% (17%)	-24%
Hard coal share in gross generation (share of total gross hard coal-fired generation in EU-28)	48% (35%)	-6%
RES share in gross generation (target for 2030)[3]	15% (32%)	43%
	Installed capacity	
Total lignite-fired capacity installed (share of total EU-28)	8.8 GW (16%)	-9%
Share of lignite-fired capacity installed before 1990 (share of total EU-28)	73% (12%)	-7%
Total hard coal-fired capacity installed (share of total EU-28)	22 GW (22%)	9%
Share of hard coal-fired capacity installed before 1990 (share of total EU-28)	67% (29%)	-7%

Note: [1] CO_2 emissions from electricity producers based on power plants identified in Oeko-Institut's EU ETS database.
[2] Emission factor calculated based on CO_2 emissions by power plants identified in Oeko-Institut's EU ETS database and gross electricity production reported by Ember (2020).
[3] According to Article 4 (2) Regulation (EU) 2018/1999, MSs have to provide information on their contribution to the Union's binding renewable energy target of at least 32% expressed as renewable energy share on gross final energy consumption. They do so in their NECPs (Article 3(2)(b)). Along with this contribution they also have to report on *estimated trajectories for the sectoral share of renewable energy in final energy consumption from 2021 to 2030 in the electricity, heating and cooling, and transport sector* (see Annex I Regulation (EU) 2018/1999 which sets out the structure of the NECPs)
Source: Own table based on Ember (2020), EC n.d., Europe Beyond Coal (2022), and EEA (2021).

Romania

- In 2019, combustion installations (Activity Code 20) in Romania emitted 22 Mt CO_2, which made Romania the 10th largest emitter (2 %) in this category. Electricity producers account for 81 % of emissions under this category. Between 2013 and 2019, emissions from electricity generators decreased by 25 %.
- Romania has a diverse generation mix. Lignite-fired generation accounted for 22 % of generation in 2019, falling from 36 % in 2005. Hard coal contributes a share of 2% in 2019, while in 2013 generation amounted to 0.4 TWh or 65 % lower. Both hard coal and lignite are supplied from domestic mines. The entire coal-fired generation fleet was installed before 1990. Nuclear power was expanded in 2007 and has provided 20 % of total production since then. Electricity generation from natural gas contributed around 15 % of total production in the period 2005 to 2019.
- Electricity supply from renewables comprised 41 % of total generation in 2019. Hydro power is a traditional RES-E source in Romania, generating 15 to 20 TWh and contributing 63 % of the RES-E share in 2019. Wind and solar supply were expanded rapidly between 2010 and 2015, and have stagnated since then.
- The emission factor of gross electricity production of 0.30 t CO_2 per MWh is about 30 % higher as the value for the EU-28 in 2019. With decreasing lignite-fired generation and increasing RES-E supply, the emission factor has decreased by more than 25 % since 2013.
- Romania was an exporter of electricity in the European electricity system, in particular in times of high hydro power generation and increasing wind and solar PV supply. With higher CO_2 prices and low hydro power generation, Romania became an importer of electricity in 2019.
- A coal phase-out is planned for 2032. In parallel, there are plans to refurbish the existing nuclear power plants and to build a new one by 2031.

Table 8: Romania: Key figures on the electricity sector in 2019

	2019	% change compared to 2013
	CO_2 emissions	
Total CO_2 emissions in 2019 from ETS Activity Code 20 (share of EU-28)	22 Mt CO_2 (2%)	-27%
Total CO_2 emissions from electricity producers[1] (share of Activity Code 20in the country)	18 Mt CO_2 (81%)	-25%
Emission factor of gross electricity production[2] (relative to EU-28 average)	0.3 t CO_2/MWh (124%)	-28%
	Gross electricity generation	
Total (share of total EU-28)	61 TWh (2%)	4%
Net electricity imports	1 TWh	-174%
Lignite share in gross generation (share of total gross lignite-fired generation in EU-28)	22% (5%)	-19%
Hard coal share in gross generation (share of total gross hard coal-fired generation in EU-28)	2% (1%)	193%
RES share in gross generation (target for 2030)[3]	41% (49%)	19%
	Installed capacity	
Total lignite-fired capacity installed (share of total EU-28)	4.6 GW (9%)	-14%
Share of lignite-fired capacity installed before 1990 (share of total EU-28)	100% (8%)	0%
Total hard coal-fired capacity installed (share of total EU-28)	1.3 GW (1%)	0%
Share of hard coal-fired capacity installed before 1990 (share of total EU-28)	100% (2%)	0%

Note: [1] CO_2 emissions from electricity producers based on power plants identified in Oeko-Institut's EU ETS database.
[2] Emission factor calculated based on CO_2 emissions by power plants identified in Oeko-Institut's EU ETS database and gross electricity production reported by Ember (2020).
[3] According to Article 4 (2) Regulation (EU) 2018/1999, MSs have to provide information on their contribution to the Union's binding renewable energy target of at least 32% expressed as renewable energy share on gross final energy consumption. They do so in their NECPs (Article 3(2)(b)). Along with this contribution they also have to report on *estimated trajectories for the sectoral share of renewable energy in final energy consumption from 2021 to 2030 in the electricity, heating and cooling, and transport sector* (see Annex I Regulation (EU) 2018/1999 which sets out the structure of the NECPs)
Source: Own table based on Ember (2020), EC n.d., Europe Beyond Coal (2022), and EEA (2021).

Spain

- In 2019, combustion installations (Activity Code 20) in Spain emitted 55 Mt $_{CO2}$, which made Spain the 5th largest emitter (6%) in this category. Electricity producers account for 75 % of emissions under this category. Between 2013 and 2019, emissions from electricity generators decreased by 31 %.
- Spain has a diverse generation mix. Gas-fired generation comprised about 30 % of gross electricity production in 2019. Coal contributed a share of 4 % in 2019, reducing its generation by more than two thirds since 2013. All lignite-fired units and more than 80 % of the hard coal-fired units were installed before 1990. Nuclear power contributes a constant share of 20 %. Electricity generation from other fossil fuels (such as waste gases from refineries and steelmaking) halved between 2005 and 2013 and comprised only 6 % of total generation in 2019.
- The emission factor of gross electricity production of 0.15 t CO_2 per MWh is 40 % below the level for the EU-28. With decreasing generation by coal and other fossil fuels, the emission factor has decreased by almost 30 % since 2013.
- Electricity supply from renewables comprised 37 % of total generation in 2019. Hydro power is a traditional RES-E source in Spain with strong variation in generation levels between 21 TWh and 46 TWh. Solar PV and wind generation saw a boom between 2005 and 2013. Due to a change in regulation, the RES-E build-up has halted since 2014 and the RES-E share decreased from its 41 % peak in 2013 due to a strong decrease in electricity generation from hydro power between 2013 and 2019. The number of installations gained new traction in 2019. Ambitious plans to increase the RES-E share to 74 % by 2030 through a new ramp-up in wind and solar capacities are backed by a new support scheme.
- Spain has changed its position in the Southwest-European electricity system from a net exporter until 2015 to a net importer since that year.
- A coal phase-out is planned for 2030; the last lignite-fired unit closed in 2020. It is planned that nuclear power will be phased out between 2025 and 2035, entailing a life-time extension beyond the 40-year limit. It is intended that a capacity market will contribute to the installation of a total of 20 GW of storage capacity by 2030.

Table 9: Spain: Key figures on the electricity sector in 2019

	2019	% change compared to 2013
	CO_2 emissions	
Total CO_2 emissions in 2019 from ETS Activity Code 20 (share of EU-28)	55 Mt CO_2 (6%)	-22%
Total CO_2 emissions from electricity producers[1] (share of Activity Code 20in the country)	41 Mt CO_2 (75%)	-31%
Emission factor of gross electricity production[2] (relative to EU-28 average)	0.15 t CO_2/MWh (63%)	-27%
	Gross electricity generation	
Total (share of total EU-28)	273 TWh (8%)	-4%
Net electricity imports	7 TWh	-196%
Lignite share in gross generation (share of total gross lignite-fired generation in EU-28)	0.2% (0.2%)	-
Hard coal share in gross generation (share of total gross hard coal-fired generation in EU-28)	4% (5%)	-74%
RES share in gross generation (target for 2030)[3]	37% (74%)	-8%
	Installed capacity	
Total lignite-fired capacity installed (share of total EU-28)	1.1 GW (2%)	0%
Share of lignite-fired capacity installed before 1990 (share of total EU-28)	100% (2%)	0%
Total hard coal-fired capacity installed (share of total EU-28)	9 GW (9%)	-14%
Share of hard coal-fired capacity installed before 1990 (share of total EU-28)	83% (8%)	-9%

Note: [1] CO_2 emissions from electricity producers based on power plants identified in Oeko-Institut's EU ETS database.
[2] Emission factor calculated based CO_2 emissions by power plants identified in Oeko-Institut's EU ETS database and gross electricity production reported by Ember (2020).
[3] According to Article 4 (2) Regulation (EU) 2018/1999, MSs have to provide information on their contribution to the Union's binding renewable energy target of at least 32 % expressed as renewable energy share on gross final energy consumption. They do so in their NECPs (Article 3(2)(b)). Along with this contribution they also have to report on *estimated trajectories for the sectoral share of renewable energy in final energy consumption from 2021 to 2030 in the electricity, heating and cooling, and transport sector* (see Annex I Regulation (EU) 2018/1999 which sets out the structure of the NECPs)
Source: Own table based on Ember (2020), EC n.d., Europe Beyond Coal (2022), and EEA (2021).

United Kingdom

- In 2019, combustion installations (Activity Code 20) in the United Kingdom emitted 81 Mt $_{CO2}$, which made it the 4th largest emitter (9 %) in this category. Electricity producers account for only 59 % of emissions under this category. Between 2013 and 2019, emissions from electricity generators decreased by 67 %.
- The United Kingdom generation mix is dominated by gas-fired generation, which accounted for 40 % of generation in 2019, increasing from 27 % in 2013. Hard coal contributes a share of 2 % in 2019, while in 2013 generation was at 130 TWh or 18 times higher. Due to stronger EU air quality regulations and the introduction of a carbon floor price in 2013, many coal-fired units were retired instead of being retrofitted or were converted to biomass-firing. The entire remaining coal-fired generation fleet was installed before 1990. Nuclear power provides about 20 % of total production.
- Electricity supply from renewables makes up 38 % of total generation in 2019, which is an increase by 143 % since 2013. A rapid expansion of wind and solar capacities started in 2011; biomass-based generation has expanded since 2013.
- The emission factor of gross electricity production of 0.15 t CO_2 per MWh is about 40 % lower than the value for the EU-28 in 2019. With decreasing coal-fired generation and increasing RES-E supply, the emission factor has decreased by 64 % since 2013.
- The United Kingdom is a major importer of electricity in the European electricity system. Imports originating from France, the Netherlands and Belgium comprise 6 % of gross electricity consumption. A new interconnector with Norway started trading in October 2021.
- A coal phase-out is planned for late 2024. In parallel, the 3.3 GW nuclear power plant Hinkley Point C is under construction. After several delays, the first block is scheduled to go online in 2031. The power plant is financed through a flexible market premium (contract for difference).

Table 10: United Kingdom: Key figures on the electricity sector in 2019

	2019	% change compared to 2013
	CO2 emissions	
Total CO_2 emissions in 2019 from ETS Activity Code 20 (share of EU-28)	81 Mt CO_2 (9%)	-54%
Total CO_2 emissions from electricity producers[1] (share of Activity Code 20in the country)	48 Mt CO_2 (59%)	-67%
Emission factor of gross electricity production[2] (relative to EU-28 average)	0.15 t CO_2/MWh (63%)	-64%
	Gross electricity generation	
Total (share of total EU-28)	322 TWh (10%)	-10%
Net electricity imports	22 TWh	53%
Lignite share in gross generation (share of total gross lignite-fired generation in EU-28)	0% (0%)	0%
Hard coal share in gross generation (share of total gross hard coal-fired generation in EU-28)	2% (3%)	-94%
RES share in gross generation (target for 2030)[3]	38% (50% - 75%)	143%
	Installed capacity	
Total lignite-fired capacity installed (share of total EU-28)	0 GW (0%)	0%
Share of lignite-fired capacity installed before 1990 (share of total EU-28)	0%	0%
Total hard coal-fired capacity installed (share of total EU-28)	12.4 GW (13%)	-55%
Share of hard coal-fired capacity installed before 1990 (share of total EU-28)	100% (12%)	0%

Note: [1] CO_2 emissions from electricity producers based on power plants identified in Oeko-Institut's EU ETS database.
[2] Emission factor calculated based on CO_2 emissions by power plants identified in Oeko-Institut's EU ETS database and gross electricity production reported by Ember (2020).
[3] According to Article 4 (2) Regulation (EU) 2018/1999, MSs have to provide information on their contribution to the Union's binding renewable energy target of at least 32% expressed as renewable energy share on gross final energy consumption. They do so in their NECPs (Article 3(2)(b)). Along with this contribution they also have to report on *estimated trajectories for the sectoral share of renewable energy in final energy consumption from 2021 to 2030 in the electricity, heating and cooling, and transport sector* (see Annex I Regulation (EU) 2018/1999 which sets out the structure of the NECPs)
Source: Own table based on Ember (2020), EC n.d., Europe Beyond Coal (2022), and EEA (2021).

Zusammenfassung

Die Erzeugung von Strom und Wärme ist die größte Einzelaktivität, die unter das EU-Emissionshandelssystem (EU EHS) fällt. Die unter Activity Code 20 zusammengefassten Verbrennungsanlagen machen 63 % der Gesamtemissionen aus, die 2019 unter das EU-Emissionshandelssystem fielen. Nach unseren Recherchen handelt es sich bei mehr als 81 % dieser Anlagen um Anlagen der Stromerzeugung oder Kraft-Wärme-Kopplungsanlagen, also Kraftwerke. Aufgrund der Vernetzung, der unterschiedlichen Emissionsintensität der verschiedenen Brennstoffe und ihrer Organisation in einem wettbewerbsorientierten Markt mit Grenzkostenbasierter Bepreisung verfügten Kraftwerke über ein großes Potenzial den Kraftwerkseinsatz durch das Preissignal des EU EHS in Richtung eines „saubereren Einsatz" auszurichten.

Die dynamische Entwicklung eines integrierten und liberalisierten europäischen Elektrizitätsmarktes, eine heterogene Ausstattung der Erzeugungsflotten in Bezug auf Erzeugungstechnologie, Primärenergieträger und Geschäftsmodell, die schnelle, aber diversifizierte Einführung erneuerbarer Energien – all dies hat sich in einem Umfeld schwankender Primärenergieträgerpreise und eines sich abzeichnenden, aber zumeist sehr geringen CO_2-Preises im EU EHS gemeinsam entwickelt. Der vorliegende Bericht versucht, Licht in diese Entwicklung zu bringen.

Dieser Bericht soll die wichtigsten Entwicklungen des Sektors im Zeitraum von 2005 bis 2019 beschreiben, d. h. vor dem Ende der dritten ETS-Handelsperiode im Jahr 2020 und vor den bedeutenden Einschnitten in der Wirtschaftsaktivität, die als Folge der COVID-Pandemie in 2020 und den folgenden Jahren aufgetreten sind. Auch die seit 2019 erfolgten Änderungen der makroökonomischen Rahmenbedingungen könnten ebenso wenig berücksichtigt werden wie die potenziellen Auswirkungen des "Fit-for-55"-Paket, das im Jahr 2023 in Gesetzen niedergelegt wurde. Dieses Reformpaket sieht Änderungen der ETS-Emissionsobergrenzen und die Einführung eines "Kohlenstoffgrenzausgleichsmechanismus" (CBAM) vor, der die kostenlosen Zuteilungen für Industriesektoren, einschließlich der Eisen- und Stahlindustrie, schrittweise ersetzen soll. Darüber hinaus sind die Preise für Emissionsberechtigungen seit 2018 erheblich gestiegen und haben dies auch nach 2019 fortgesetzt (siehe z. B. DEHSt (2024) für eine grafische Darstellung der beobachteten Preisentwicklung), was zumindest teilweise auf eine zunehmende Wahrnehmung der Knappheit auf dem Markt zurückzuführen ist.

Die vorliegende Analyse ermöglicht es, die wichtigsten Faktoren für die Entwicklung von Kapazitäten, Erzeugungsmengen und Emissionen nachzuvollziehen. Damit liefert er Schlüsselinformationen aus der Vergangenheit, die die Grundlage für künftige Prognosen und die Gestaltung von maßgeschneiderten politischen Instrumenten bilden.

Der Bericht bietet Informationen auf europäischer Ebene sowie für 10 ausgewählte europäische Länder in Form von kurzen Faktenblättern. Um ein umfassendes Bild der nationalen Trends in der EU zu erhalten, wurden die folgenden Länder für Kurzdarstellungen ausgewählt: die Tschechische Republik, Estland, Frankreich, Deutschland, Italien, die Niederlande, Polen, Rumänien, Spanien und das Vereinigte Königreich.

Die Emissionen im Zusammenhang mit dem Activity Code 20 (Verbrennungsanlagen) sind in den letzten Jahren in den Ländern, die unter das EU EHS fallen, drastisch zurückgegangen. Abbildung 1zeigt die Emissionstrends von Feuerungsanlagen in der EU-28 zwischen 2010 und 2019 auf der Grundlage von (EC n.d.)-Daten und unserer eigenen Forschung. Die Kraftwerke werden in der Abbildung nach Brennstoff unterschieden.

Auf Braun- und Steinkohlekraftwerke entfielen im Jahr 2013 rund 65 % aller unter den Activity Code 20 fallenden Emissionen. Dieser Anteil sank auf 47 % im Jahr 2019. Die Emissionen aus Braunkohlekraftwerken belaufen sich im Jahr 2019 auf ca. 260 Mio t CO_2, was einem Rückgang von 27 % gegenüber 2013 entspricht. Die Emissionen aus Steinkohlekraftwerken beliefen sich im Jahr 2019 auf 200 Mio. t CO_2, was einem Rückgang von 59 % gegenüber 2013 entspricht. Im gleichen Zeitraum blieben die Emissionen aus Hochofenkraftwerken mit 53 Mio. t CO_2 unverändert. Die Emissionen aus der Kategorie "Sonstige Verbrennung (Activity Code 20; Power Marker)", zu der erdgas- und ölbefeuerte sowie sonstige Kraftwerke gehören, stiegen nur um 3 % von 252 Mio. t CO_2 im Jahr 2013 auf 260 Mio. t CO_2 im Jahr 2019.

Der stärkste Rückgang erfolgte jedoch zwischen 2018 und 2019: Innerhalb eines Jahres sanken die Emissionen der Kraftwerke um 142 Mio. t CO_2. Steinkohlekraftwerke trugen am meisten zu dieser Verringerung bei (91 Mio. t CO_2 aus Steinkohlekraftwerken). Braunkohlekraftwerke trugen 57 Mio. t CO_2 bei. Die Emissionen aus anderen Kraftwerken (hauptsächlich erdgasbefeuerte Kraftwerke) stiegen von 2018 auf 2019 um etwa 10 Mio. t CO_2.

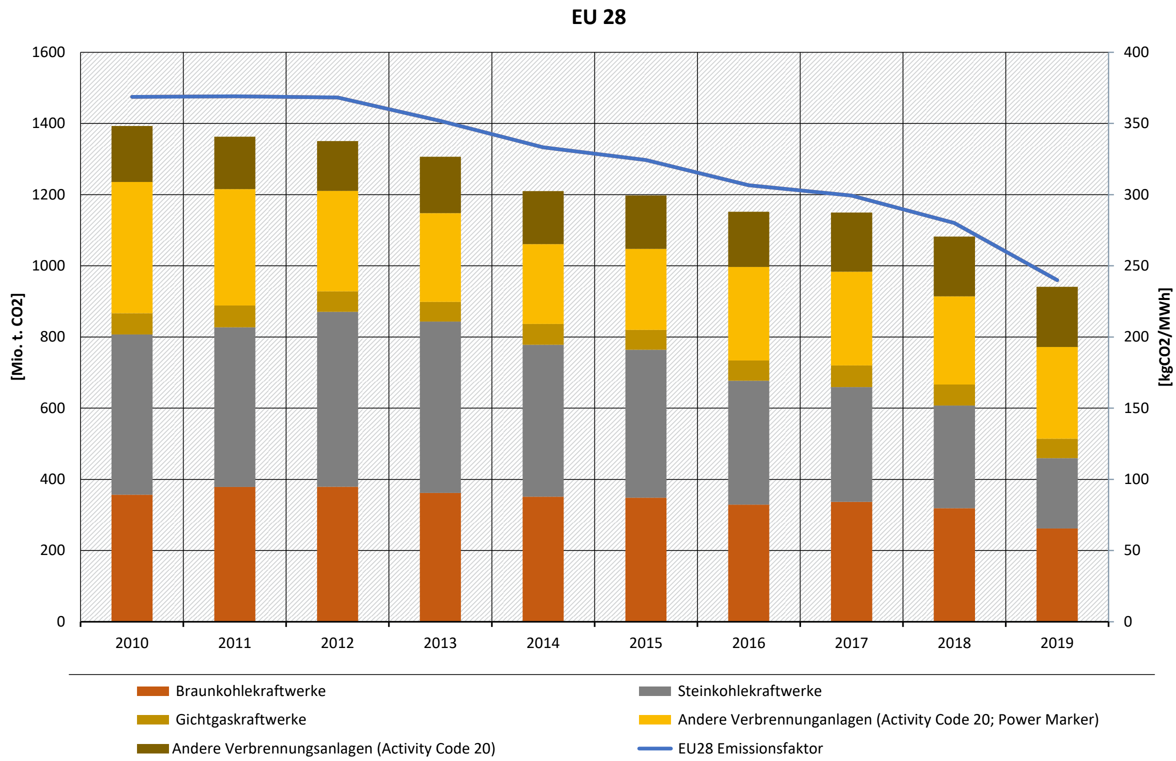
Die Kategorie "Sonstige Verbrennung (Activity Code 20)" umfasst die nicht stromerzeugenden Anlagen und blieb zwischen 2010 und 2019 stabil.

Abbildung 1 enthält auch den Emissionsfaktor der Bruttostromerzeugung in der EU-28. Er ist von 370 kg CO_2/MWh im Jahr 2010 auf 240 kg CO_2/MWh im Jahr 2019 gesunken.

Bedingt durch den anhaltenden Rückgang der Kohleverstromung aufgrund der hohen Preise im EU EHS, aber auch durch die geringere Nachfrage während der COVID-19-Pandemie, setzte sich der rückläufige Trend auch im Jahr 2020 fort. In den Jahren 2021 und 2022, dem Beginn der vierten Handelsperiode, stiegen die Emissionen zunächst wieder an. Dies war auf eine höhere Stromnachfrage infolge der wirtschaftlichen Erholung nach der COVID-19-Pandemie sowie auf eine Verschiebung der relativen Kosten für die Kohleverstromung gegenüber erdgasbasierter Stromerzeugung infolge des russischen Angriffskriegs gegen die Ukraine und den damit verbundenen Anstieg der Emissionen aus der Verbrennung von Stein- und Braunkohle zurückzuführen. Dieser kurzzeitige Trend in der Kohleverstromung kehrte sich 2023 um. Infolgedessen gingen die Emissionen aus der Kraftwerkserzeugung deutlich zurück und erreichten den niedrigsten Stand seit Beginn des EU-EHS im Jahr 2005. Dies ist vor allem auf den starken Rückgang der Energienachfrage von Industrie und Haushalten zurückzuführen, der durch stark gestiegene Energiepreise verursacht wurde.

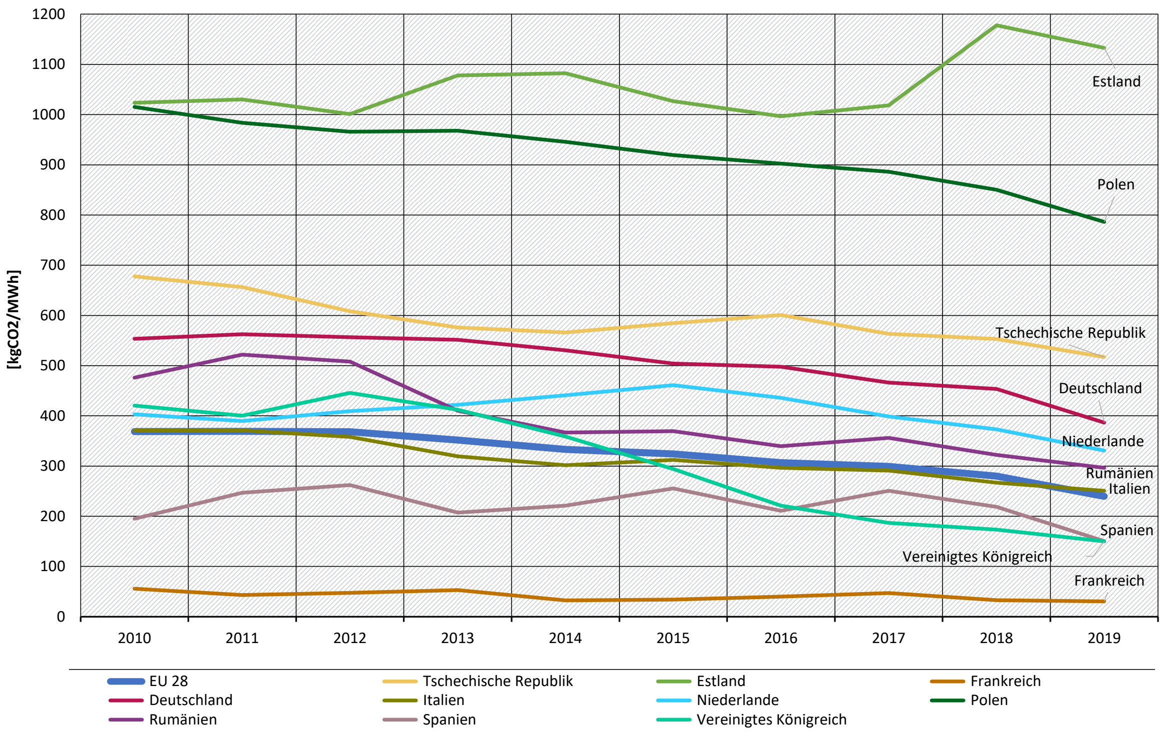
Abbildung 2 zeigt die Entwicklung der Emissionsfaktoren für die EU-28 und für die zehn für diese Studie ausgewählten Länder im direkten Vergleich zwischen 2010 und 2019. Estland, Polen, die Tschechische Republik, Deutschland, die Niederlande und Rumänien hatten während des gesamten Zeitraums eine emissionsintensivere Stromerzeugung als der Durchschnitt der EU-28. Der Trend des Emissionsfaktors von Italien ist dem der EU-28 recht ähnlich, während das Vereinigte Königreich von höheren Emissionsfaktoren als der EU-Durchschnitt bis 2014 zu niedrigeren Emissionsfaktoren ab 2015 überging. Die Emissionsfaktoren Spaniens und Frankreichs lagen im betrachteten Zeitraum stets unter den Werten der EU-28. In den nachfolgenden Einzelkapiteln werden die Gründe für diese sehr unterschiedlichen Emissionsfaktorniveaus genauer untersucht

Abbildung 1: EU-28 Emissiontrends in Activity Code 20



Anmerkung: Die Werte für Kroatien wurden für die Jahre 2010-2012 extrapoliert, wobei die Daten des gesamten Treibhausgasinventars als Proxy für Emissionstrends verwendet wurden. Emissionen in der Kategorie: Sonstige Verbrennungsanlagen (Activity Code 20; Power Marker) werden nach dem Abzugsverfahren berechnet: Alle Emissionen mit Power Marker minus Emissionen aus Braun- und Steinkohlekraftwerken minus Emissionen aus Gichtgaskraftwerken.
Quelle: Eigene Darstellung basierend auf Daten von Europe Beyond Coal (2022), EEA (2022), Ember (2020), und eigener Zuordnung basierend auf EC n.d..

Abbildung 2: Emissionsfaktor der Bruttostromerzeugungfür die EU-28 und ausgewählte Länder



Hinweis: Der Emissionsfaktor wurde auf der Grundlage der CO_2-Emissionen der in der EU-ETS-Datenbank des Öko-Instituts identifizierten Kraftwerke und der von Ember (2020) gemeldeten Bruttostromerzeugung berechnet. Dieser kann von den bei der Europäischen Umweltagentur (EEA, 2021) angegebenen Werten abweichen.
Quelle: Eigene Darstellung basierend auf DatenEurope Beyond Coal (2022) von EEA (2021), Ember (2020), und eigener Zuordnung basierend auf EC n.d..

Auf den folgenden Seiten werden die Kernaussagen der Länderprofile zusammengefasst.

Tschechische Republik

- 2019 emittierten Verbrennungs- und Energieanlagen (Activity Code 20) in der Tschechischen Republik 49 Mt CO_2, womit die Tschechische Republik der siebtgrößte Emittent (5 %) in dieser Kategorie war. Die Stromerzeugung sind für 90 % der Emissionen in dieser Kategorie verantwortlich. Zwischen 2013 und 2019 gingen die Emissionen der Stromerzeugung nur um 11 % zurück (ähnlich wie in den Niederlanden; in allen anderen untersuchten Mitgliedstaaten sanken die strombezogenen Emissionen stärker).
- Der Erzeugungsmix wird von der Braunkohleverstromung dominiert (41 %). Steinkohle hat einen geringen Anteil von nur 2 %. Während letztere zwischen 2013 und 2019 um 75 % zurückging, sank erstere nur um 1 %. Über 80 % des Kohlekraftwerksparks wurde vor 1990 errichtet. Die Kernenergie ist die zweite Säule der Stromerzeugung und trägt zu etwa einem Drittel zur Gesamterzeugung bei. Die Gaskapazität ist seit 2013 auf 2 GW gestiegen, hat aber ihren Anteil an der Erzeugung nur erhöht, als die CO_2-Preise 2018 und 2019 stiegen.
- Der Anteil der Stromerzeugung aus erneuerbaren Energien war mit 13 % im Jahr 2019 gering und zeigte in den letzten Jahren keine starke Dynamik.
- Die Tschechische Republik ist ein Nettoexporteur von Strom im mitteleuropäischen Stromsystem. Aufgrund ihrer Lage im System stellt sie in Zeiten hoher Winderzeugung im Norden auch Transitkapazitäten für die Erzeugung von Norddeutschland nach Süddeutschland bereit (Loop Flows). Diese Ringflüsse sind in den letzten Jahren mit der steigenden Nachfrage in Polen und der Installation von Phasenschiebern zurückgegangen.
- Die Kohleverstromung wird vom staatlichen Unternehmen ČEZ dominiert (60 % der Kohleverstromung im Jahr 2019). Eine von der Regierung im Dezember 2020 einberufene nationale Kohlekommission hat einen Kohleausstieg bis 2038 empfohlen. Im Januar 2022 kündigte die neue tschechische Mitte-Rechts-Regierung, die im Oktober 2021 gewählt worden war, ihre Absicht an, bis 2033 aus der Kohleverstromung auszusteigen; zum Zeitpunkt der Fertigstellung dieses Berichts waren die Pläne noch nicht in Gesetzesform gegossen.

Tabelle 1: Tschechische Republik: Schlüsselindikatoren zum Stromsektor im Jahr 2019

	2019	% Veränderung im Vergleich zu 2013
	CO_2 Emissionen	
Gesamte CO_2-Emissionen im Jahr 2019 Activity Code 20 (Anteil an EU-28)	49 Mio. t CO_2 (5%)	-11%
Gesamte CO_2-Emissionen der Stromerzeugung[1] (Anteil Activity Code 20 im Land)	45 Mio. t CO_2 (90%)	-11%
Emissionsfaktor der Bruttostromerzeugung[2] (relativ zum EU-28-Durchschnitt)	0,52 t CO_2/MWh (216%)	-10%
	Bruttostromerzeugung	
Insgesamt (Anteil an EU-28 insgesamt)	86 TWh (3%)	0%
Netto-Stromimport	-13 TWh	-26%
Anteil der Braunkohle an der Bruttostromerzeugung (Anteil an gesamten Brutto-BK-Verstromung in der EU-28)	41% (14%)	-1%
Anteil der Steinkohle an der Bruttostromerzeugung (Anteil an gesamten Brutto-SK-Verstromung in der EU-28)	2% (1%)	-75%
Anteil erneuerbarer Energien an der Bruttoerzeugung (Ziel für 2030)[3]	13% (17%)	10%
	Installierte Kapazität	
Gesamte installierte BK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	7,8 GW (15%)	-4%
Anteil der vor 1990 installierten BK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	81% (13%)	-5%
Gesamte installierte SK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	1,4 GW (1%)	-3%
Anteil der vor 1990 installierten SK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	85% (2%)	-6%

Anmerkung: [1] CO_2-Emissionen der Stromerzeugung auf Basis der in der EU-EHS-Datenbank des Öko-Instituts identifizierten Kraftwerke. [2] Emissionsfaktor berechnet auf Basis der CO_2-Emissionen der in der EU-EHS-Datenbank des Öko-Instituts identifizierten Kraftwerke und der von Ember (2020) gemeldeten Bruttostromerzeugung. [3] Gemäß Artikel 4 (2) der Verordnung (EU) 2018/1999 müssen die Mitgliedstaaten Informationen über ihren Beitrag zur Erreichung des verbindlichen Ziels der Union für erneuerbare Energien von mindestens 32 %, ausgedrückt als Anteil erneuerbarer Energien am Bruttoendenergieverbrauch, vorlegen. Sie tun dies in ihren NECP (Artikel 3 Absatz 2 Buchstabe b). Zusammen mit diesem Beitrag müssen sie auch über die geschätzten Zielpfade für den sektoralen Anteil erneuerbarer Energien am Endenergieverbrauch von 2021 bis 2030 in den Sektoren Strom, Wärme und Kälte sowie Verkehr berichten (siehe Anhang I der Verordnung (EU) 2018/1999, in dem die Struktur der NECP dargelegt ist)

Quelle: Eigene Darstellung basierend auf Ember (2020), EC n.d., Europe Beyond Coal (2022), und EEA (2021).

Estland

- 2019 emittierten Verbrennungs- und Energieanlagen (Activity Code 20) in Estland 6 Mio. t CO_2, womit Estland der 22. größte Emittent (1 %) in dieser Kategorie war. Stromerzeugung ist für 96 % der Emissionen in dieser Kategorie verantwortlich. Zwischen 2013 und 2019 sind die Emissionen der Stromerzeugung um 57 % zurückgegangen.
- Der Erzeugungsmix wird von der mit Ölschiefer befeuerten Erzeugung dominiert, die zwischen 2005 und 2018 mehr als 85 % der Gesamterzeugung ausmachte. Mit dem steigenden CO_2-Preis ist der Anteil 2019 auf unter 80 % gesunken.
- Estland ist zunehmend mit seinen Nachbarländern verflochten. Die Position des Landes auf dem Nordpool-Strommarkt reagiert stark auf CO_2-Preissignale. Mit steigenden CO_2-Preisen hat sich das Land von einem Nettoexporteur von Strom, der in den Jahren vor 2019 20 % oder mehr seiner Erzeugung exportierte, zu einem Nettoimporteur entwickelt, der 2019 fast 30 % des Verbrauchs durch Importe deckte.
- Aufgrund der zentralen Rolle von Ölschiefer bei der Stromerzeugung liegt der durchschnittliche Emissionsfaktor der Bruttostromerzeugung bei etwa 1,0 Mt CO_2 pro MWh und damit mehr als viermal so hoch wie der durchschnittliche Emissionsfaktor der EU-28 im Jahr 2019.
- Die Energieversorgung aus erneuerbaren Quellen spielt eine zunehmende Rolle und machte 2019 22 % der gesamten Bruttostromerzeugung aus, was einem Anstieg von etwa 140 % gegenüber 2013 entspricht.
- Die neue estnische Koalition plant, die Stromerzeugung aus Ölschiefer bis 2035 einzustellen und bis 2030 einen Anteil von 40 % erneuerbarer Energien an der Stromerzeugung zu erreichen. Sie will dies vor allem durch den Ausbau der Windenergie erreichen, hat aber auch eine Arbeitsgruppe eingesetzt, die die Aussichten für die Einführung der Kernenergie in Estland prüfen soll.

Tabelle 2: Estland: Schlüsselindikatoren zum Stromsektor im Jahr 2019

	2019	% Veränderung im Vergleich zu 2013
	CO_2 Emissionen	
Gesamte CO_2-Emissionen im Jahr 2019 aus Activity Code 20 (Anteil an EU-28)	6 Mt CO_2 (1%)	-56%
Gesamte CO_2-Emissionen der Stromerzeugung[1] (Anteil Activity Code 20 im Land)	6 Mt CO_2 (96%)	-57%
Emissionsfaktor der Bruttostromerzeugung[2] (relativ zum EU-28-Durchschnitt)	0,99 t CO_2/MWh (414%)	-5%
	Bruttostromerzeugung	
Insgesamt (Anteil an EU-28 insgesamt)	6 TWh (0%)	-55%
Netto-Stromimport	2 TWh	-162%
Anteil der Braunkohle an der Bruttostromerzeugung (Anteil an gesamten Brutto-BK-Verstromung in der EU-28)	0% (0%)	0%
Anteil der Steinkohle an der Bruttostromerzeugung (Anteil an gesamten Brutto-SK-Verstromung in der EU-28)	0% (0%)	0%
Anteil erneuerbarer Energien an der Bruttoerzeugung (Ziel für 2030)[3]	22% (40%)	138%
	Installierte Kapazität	
Gesamte installierte BK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	0	
Anteil der vor 1990 installierten BK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	0	
Gesamte installierte SK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	0	
Anteil der vor 1990 installierten SK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	0	

Anmerkung: [1] CO_2-Emissionen der Stromerzeugung auf Basis der in der EU EHS-Datenbank des Öko-Instituts identifizierten Kraftwerke. [2] Emissionsfaktor berechnet auf Basis der CO_2-Emissionen der in der EU EHS-Datenbank des Öko-Instituts identifizierten Kraftwerke und der von Ember (2020) gemeldeten Bruttostromerzeugung. [3] Gemäß Artikel 4 (2) der Verordnung (EU) 2018/1999 müssen die Mitgliedstaaten Informationen über ihren Beitrag zur Erreichung des verbindlichen Ziels der Union für erneuerbare Energien von mindestens 32 %, ausgedrückt als Anteil erneuerbarer Energien am Bruttoendenergieverbrauch, vorlegen. Sie tun dies in ihren NECP (Artikel 3 Absatz 2 Buchstabe b). Zusammen mit diesem Beitrag müssen sie auch über die geschätzten Zielpfade für den sektoralen Anteil erneuerbarer Energien am Endenergieverbrauch von 2021 bis 2030 in den Sektoren Strom, Wärme und Kälte sowie Verkehr berichten (siehe Anhang I der Verordnung (EU) 2018/1999, in dem die Struktur der NECP dargelegt ist)

Quelle: Eigene Darstellung basierend auf Ember (2020), EC n.d., Europe Beyond Coal (2022), und EEA (2021).

Frankreich

- 2019 emittierten Verbrennungs- und Energieanlagen (Activity Code 20) in Frankreich 43 Mio. t CO_2, was Frankreich zum achtgrößten Emittenten (5 %) in dieser Kategorie machte. Auf die Stromerzeugung entfallen nur 41 % der Emissionen in dieser Kategorie; das ist viel weniger als in den anderen analysierten Mitgliedstaaten, in denen der Anteil bei 75 % oder höher liegt (eine weitere Ausnahme ist das Vereinigte Königreich). Zwischen 2013 und 2019 sind die Emissionen der Stromerzeugung um 43 % zurückgegangen.
- Die Kohleverstromung ging in zwei Wellen zurück: in den Jahren 2013 bis 2015, als eine Kombination aus Luftverschmutzungsvorschriften und dem Beginn der Versteigerung von EU EHS-Zertifikaten für die Stromerzeugung anstelle der kostenlosen Zuteilung den Weiterbetrieb einiger Kraftwerke finanziell unattraktiv machte, und in den Jahren 2018 und 2019, als höhere CO_2-Preise einen Brennstoffwechsel von Kohle zu Gas bewirkten.
- Frankreich ist ein wichtiger Stromexporteur im mitteleuropäischen Stromsystem, mit 50 TWh Exporten im Durchschnitt zwischen 2005 und 2019. Der Strom wird vor allem in das Vereinigte Königreich und nach Italien exportiert. In geringerem Umfang wird auch Strom nach Deutschland und Spanien exportiert.
- Der Kohleausstieg ist für 2027 geplant, später als ursprünglich vorgesehen. Die Kernkraftwerksflotte wird in den kommenden Jahren erhebliche Neuinvestitionen erfordern; 30 % der Anlagen sind älter als 40 Jahre und 88 % sind mindestens 30 Jahre alt oder älter.
- 2017 hat Frankreich einen Kapazitätsmarkt eingeführt, auf dem die Anbieter verpflichtet sind, ausreichend Kapazitätsgarantiezertifikate zu halten, die gehandelt werden können. Aufgrund des Schwellenwerts von 200 g CO_2/MWh ist die Gaserzeugung ausgeschlossen, und die Kapazitätsbereitstellung erfolgt hauptsächlich durch Kern- und Wasserkraftwerke.

Tabelle 3: Frankreich: Schlüsselindikatoren zum Stromsektor im Jahr 2019

	2019	% Veränderung im Vergleich zu 2013
	CO_2 Emissionen	
Gesamte CO_2-Emissionen im Jahr 2019 aus Activity Code 20 (Anteil an EU-28)	43 Mt CO_2 (5%)	-26%
Gesamte CO_2-Emissionen der Stromerzeugung[1] (Anteil Activity Code 20 im Land)	17 Mt CO_2 (41%)	-43%
Emissionsfaktor der Bruttostromerzeugung[2] (relativ zum EU-28-Durchschnitt)	0,03 t CO_2/MWh (13%)	-42%
	Bruttostromerzeugung	
Insgesamt (Anteil an EU-28 insgesamt)	570 TWh (18%)	-2%
Netto-Stromimport	-61 TWh	26%
Anteil der Braunkohle an der Bruttostromerzeugung (Anteil an gesamten Brutto-BK-Verstromung in der EU-28)	0% (0%)	0%
Anteil der Steinkohle an der Bruttostromerzeugung (Anteil an gesamten Brutto-SK-Verstromung in der EU-28)	1% (2%)	-83%
Anteil erneuerbarer Energien an der Bruttoerzeugung (Ziel für 2030)[3]	21% (40%)	15%
	Installierte Kapazität	
Gesamte installierte BK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	0 GW (0%)	0%
Anteil der vor 1990 installierten BK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	0%	0%
Gesamte installierte SK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	3,2 GW (3%)	-56%
Anteil der vor 1990 installierten SK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	100% (6%)	0%

Anmerkung: [1] CO_2-Emissionen der Stromerzeugung auf Basis der in der EU EHS-Datenbank des Öko-Instituts identifizierten Kraftwerke. [2] Emissionsfaktor berechnet auf Basis der CO_2-Emissionen der in der EU EHS-Datenbank des Öko-Instituts identifizierten Kraftwerke und der von Ember (2020) gemeldeten Bruttostromerzeugung. [3] Gemäß Artikel 4 (2) der Verordnung (EU) 2018/1999 müssen die Mitgliedstaaten Informationen über ihren Beitrag zur Erreichung des verbindlichen Ziels der Union für erneuerbare Energien von mindestens 32 %, ausgedrückt als Anteil erneuerbarer Energien am Bruttoendenergieverbrauch, vorlegen. Sie tun dies in ihren NECP (Artikel 3 Absatz 2 Buchstabe b). Zusammen mit diesem Beitrag müssen sie auch über die geschätzten Zielpfade für den sektoralen Anteil erneuerbarer Energien am Endenergieverbrauch von 2021 bis 2030 in den Sektoren Strom, Wärme und Kälte sowie Verkehr berichten (siehe Anhang I der Verordnung (EU) 2018/1999, in dem die Struktur der NECP dargelegt ist)

Quelle: Eigene Darstellung basierend auf Ember (2020), EC n.d., Europe Beyond Coal (2022), und EEA (2021).

Deutschland

- Im Jahr 2019 emittierten Verbrennungs- und Energieanlagen (Activity Code 20) in Deutschland 245 Mio. t CO_2, womit Deutschland der größte Emittent (26 %) in dieser Kategorie war. Die Stromerzeugung ist für 95 % der Emissionen in dieser Kategorie verantwortlich. Zwischen 2013 und 2019 sanken die Emissionen der Stromerzeugung um 33 %.
- 2019 hat Deutschland einen vielfältigen Erzeugungsmix. Der Anteil der Braunkohle- und Steinkohleverstromung liegt bei 19 % bzw. 9 %. Zwischen 2013 und 2019 sinkt die Steinkohleverstromung um 55 % und die Braunkohleverstromung um 29 %. Mehr als 55 % des kohlebefeuerten Kraftwerksparks wurde vor 1990 errichtet. Der Anteil der Gaskraftwerke lag 2019 bei 15 %, was einem Anstieg von 35 % seit 2013 entspricht. Der Anteil der Kernenergie ging zwischen 2005 und 2019 erheblich zurück, von 26 % auf 12 %. Insbesondere im Jahr 2018 und noch stärker im Jahr 2019 wurde die Kohleverstromung durch eine zunehmende Gas- und Windenergieerzeugung und einen Rückgang der Exporte kompensiert. Die Abschätzung des Brennstoffwechselpotenzials zeigt, dass zwischen Ende 2018 und Mitte 2021 die Erzeugungsgrenzkosten von Erdgaskraftwerken unter denen von Steinkohlekraftwerken lagen.
- Der Anteil der Stromerzeugung aus erneuerbaren Energien liegt 2019 bei 40 % und ist zwischen 2013 und 2019 um 66 % gestiegen. Der Plan, diesen Anteil bis 2030 auf 80 % zu erhöhen, stützt sich auf einen starken Ausbau der Wind- und Solarstromkapazitäten. Die Stromerzeugung aus Biomasse nahm bis 2015 zu und ist seither stabil geblieben.
- Aufgrund der herausragenden Rolle der Kohle bei der Stromerzeugung in Deutschland liegt der durchschnittliche Emissionsfaktor der Bruttostromerzeugung bei etwa 0,4 Mio. t CO_2 pro MWh, was 60 % über dem durchschnittlichen Emissionsfaktor der EU-28 im Jahr 2019 liegt.
- Deutschland ist ein Nettoexporteur von Strom im mitteleuropäischen Stromsystem und ist gut mit seinen Nachbarländern integriert. Interne Netzengpässe zwischen dem Norden und dem Süden sind im Marktdesign nicht berücksichtigt und haben zu Ringflüssen in Polen und der Tschechischen Republik geführt.
- Der Kohleausstieg wird bis Ende 2038 vollzogen, mit definierten Zwischenschritten in den Jahren 2022 und 2030. Der Ausstieg aus der Kernenergie wurde im April 2023 vollzogen.

Tabelle 4: Deutschland: Schlüsselindikatoren zum Stromsektor im Jahr 2019

	2019	% Veränderung im Vergleich zu 2013
	CO_2 Emissionen	
Gesamte CO_2-Emissionen im Jahr 2019 aus Activity Code 20 (Anteil an EU-28)	245 Mt CO_2 (26%)	-32%
Gesamte CO_2-Emissionen der Stromerzeugung[1] (Anteil Activity Code 20 im Land)	234 Mt CO_2 (95%)	-33%
Emissionsfaktor der Bruttostromerzeugung[2] (relativ zum EU-28-Durchschnitt)	0,39 t CO_2/MWh (161%)	-30%
	Bruttostromerzeugung	
Insgesamt (Anteil an EU-28 insgesamt)	605 TWh (19%)	-4%
Netto-Stromimport	-37 TWh	14%
Anteil der Braunkohle an der Bruttostromerzeugung (Anteil an gesamten Brutto-BK-Verstromung in der EU-28)	19% (45%)	-29%
Anteil der Steinkohle an der Bruttostromerzeugung (Anteil an gesamten Brutto-SK-Verstromung in der EU-28)	9% (26%)	-55%
Anteil erneuerbarer Energien an der Bruttoerzeugung (Ziel für 2030)[3]	40% (80%)	66%
	Installierte Kapazität	
Gesamte installierte BK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	22,1 GW (40%)	-2%
Anteil der vor 1990 installierten BK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	56% (25%)	-14%
Gesamte installierte SK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	25,4 GW (26%)	-12%
Anteil der vor 1990 installierten SK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	57% (27%)	- 18%

Anmerkung: [1] CO_2-Emissionen der Stromerzeugung auf Basis der in der EU EHS-Datenbank des Öko-Instituts identifizierten Kraftwerke. [2] Emissionsfaktor berechnet auf Basis der CO_2-Emissionen der in der EU EHS-Datenbank des Öko-Instituts identifizierten Kraftwerke und der von Ember (2020) gemeldeten Bruttostromerzeugung. [3] Gemäß Artikel 4 (2) der Verordnung (EU) 2018/1999 müssen die Mitgliedstaaten Informationen über ihren Beitrag zur Erreichung des verbindlichen Ziels der Union für erneuerbare Energien von mindestens 32 %, ausgedrückt als Anteil erneuerbarer Energien am Bruttoendenergieverbrauch, vorlegen. Sie tun dies in ihren NECP (Artikel 3 Absatz 2 Buchstabe b). Zusammen mit diesem Beitrag müssen sie auch über die geschätzten Zielpfade für den sektoralen Anteil erneuerbarer Energien am Endenergieverbrauch von 2021 bis 2030 in den Sektoren Strom, Wärme und Kälte sowie Verkehr berichten (siehe Anhang I der Verordnung (EU) 2018/1999, in dem die Struktur der NECP dargelegt ist).
Quelle: Eigene Darstellung basierend auf Ember (2020), EC n.d., Europe Beyond Coal (2022), und EEA (2021).

Italien

- 2019 emittierten Verbrennungs- und Energieanlagen (Activity Code 20) in Italien 83 Mio. t CO_2, womit Italien der drittgrößte Emittent (9 %) in dieser Kategorie war. Auf die Stromerzeugung entfallen 87 % der Emissionen in dieser Kategorie. Zwischen 2013 und 2019 sind die Emissionen der Stromerzeugung um 21 % zurückgegangen.
- Der Erzeugungsmix wird von gasgefeuerten Anlagen dominiert, die 2019 etwa 50 % der Bruttostromerzeugung ausmachen. Steinkohle hat 2019 einen Anteil von 6 %, während die Erzeugung im Jahr 2013 mit 45 TWh um 60 % höher lag. Nur ein Drittel des kohlebefeuerten Kraftwerksparks wurde vor 1990 errichtet. Der Anteil anderer fossiler Brennstoffe (z. B. Abgase aus Raffinerien und der Stahlerzeugung) ist seit 2005 stark zurückgegangen und machte 2019 nur 5 % der Gesamterzeugung aus.
- Der Emissionsfaktor der Bruttostromerzeugung liegt mit 0,25 t CO_2 pro MWh auf einem ähnlichen Niveau wie der Wert für die EU-28. Bei abnehmender Erzeugung aus Kohle und anderen fossilen Energieträgern ist er seit 2013 um mehr als 20 % gesunken.
- Der Anteil der Stromerzeugung aus erneuerbaren Energien an der Gesamterzeugung betrug im Jahr 2019 40 %. Wasserkraft ist in Italien eine traditionelle erneuerbare Energiequelle, die 40 bis 60 TWh erzeugt und 40 % des Anteils der erneuerbaren Energien an der Stromerzeugung im Jahr 2019 ausmacht. Biomasse, Wind- und Solarenergie verzeichneten bis 2014 einen raschen Ausbau und stagnierten dann bis 2018; erst 2019 nahmen die Installationen wieder zu.
- Italien ist ein wichtiger Stromimporteur im mitteleuropäischen Stromsystem mit durchschnittlich 43 TWh Importen im Zeitraum 2005 bis 2019. Entsprechend hoch sind die Strompreise, die durch die gasgefeuerte Erzeugung und die Importe bestimmt werden, im Vergleich zur Atom- oder Kohleverstromung in Frankreich oder Deutschland, den Hauptherkunftsländern der Importe (wobei Deutschland auch über die Schweiz und Österreich liefert).
- Ein für 2025 geplanter Ausstieg aus der Kohleverstromung ist mit dem Bau neuer Gaskapazitäten verbunden, die über Auktionen beschafft werden sollen. Auf Grund von Verzögerungen beim Ausbau des Anschlusses Sardiniens an das Festland, wird das dortige Kohlekraftwerk noch bis 2027 betrieben.

Tabelle 5: Italien: Schlüsselindikatoren zum Stromsektor im Jahr 2019

	2019	% Veränderung im Vergleich zu 2013
	CO_2 Emissionen	
Gesamte CO_2-Emissionen im Jahr 2019 aus Activity Code 20 (Anteil an EU-28)	83 Mt CO_2 (9%)	-18%
Gesamte CO_2-Emissionen der Stromerzeugung[1] (Anteil Activity Code 20 im Land)	72 Mt CO_2 (87%)	-21%
Emissionsfaktor der Bruttostromerzeugung[2] (relativ zum EU-28-Durchschnitt)	0,25 t CO_2/MWh (104%)	-21%
	Bruttostromerzeugung	
Insgesamt (Anteil an EU-28 insgesamt)	289 TWh (9%)	0%
Netto-Stromimport	41 TWh	-4%
Anteil der Braunkohle an der Bruttostromerzeugung (Anteil an gesamten Brutto-BK-Verstromung in der EU-28)	0% (0%)	0%
Anteil der Steinkohle an der Bruttostromerzeugung (Anteil an gesamten Brutto-SK-Verstromung in der EU-28)	6% (8%)	-59%
Anteil erneuerbarer Energien an der Bruttoerzeugung (Ziel für 2030)[3]	40% (55%)	2%
	Installierte Kapazität	
Gesamte installierte BK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	0 GW (0%)	0%
Anteil der vor 1990 installierten BK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	0%	0%
Gesamte installierte SK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	8,6 GW (9%)	-11%
Anteil der vor 1990 installierten SK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	34% (5%)	-19%

Anmerkung: [1] CO_2-Emissionen der Stromerzeugung auf Basis der in der EU-ETS-Datenbank des Öko-Instituts identifizierten Kraftwerke. [2] Emissionsfaktor berechnet auf Basis der CO_2-Emissionen der in der EU-ETS-Datenbank des Öko-Instituts identifizierten Kraftwerke und der von Ember (2020) gemeldeten Bruttostromerzeugung. [3] Gemäß Artikel 4 (2) der Verordnung (EU) 2018/1999 müssen die Mitgliedstaaten Informationen über ihren Beitrag zur Erreichung des verbindlichen Ziels der Union für erneuerbare Energien von mindestens 32 %, ausgedrückt als Anteil erneuerbarer Energien am Bruttoendenergieverbrauch, vorlegen. Sie tun dies in ihren NECP (Artikel 3 Absatz 2 Buchstabe b). Zusammen mit diesem Beitrag müssen sie auch über die geschätzten Zielpfade für den sektoralen Anteil erneuerbarer Energien am Endenergieverbrauch von 2021 bis 2030 in den Sektoren Strom, Wärme und Kälte sowie Verkehr berichten (siehe Anhang I der Verordnung (EU) 2018/1999, in dem die Struktur der NECP dargelegt ist)

Quelle: Eigene Darstellung basierend auf Ember (2020), EC n.d., Europe Beyond Coal (2022), und EEA (2021).

Niederlande

- 2019 emittierten Verbrennungs- und Energieanlagen (Activity Code 20) in den Niederlanden 54 Mio. t CO_2, was die Niederlande zum sechstgrößten Emittenten (6 %) in dieser Kategorie machte. Die Stromerzeugung ist für 74 % der Emissionen in dieser Kategorie verantwortlich. Zwischen 2013 und 2019 sind die Emissionen der Stromerzeugung nur um 11 % zurückgegangen (ähnlich wie in der Tschechischen Republik; in allen anderen untersuchten Mitgliedstaaten sind die strombezogenen Emissionen stärker zurückgegangen).

- Aufgrund der heimischen Gasreserven wird der Erzeugungsmix von der gasgefeuerten Anlagen dominiert, die zwischen 2005 und 2019 etwa 50 % bis 60 % der Bruttostromerzeugung ausmachen. Erdbeben und anschließende öffentliche Proteste führten 2018 zu der Entscheidung, die Produktion im Groningen-Feld zu drosseln; die Versorgung der inländischen Stromerzeuger war davon jedoch nicht betroffen. Der Anteil der Steinkohle lag zwischen 2005 und 2019 im Durchschnitt bei 24 %. Mit der Installation von drei neuen Blöcken im Jahr 2015 und einem im Jahr 2016 und einer Nettokapazitätssteigerung von 0,7 GW stieg der Anteil jedoch an und erreichte 2015 einen Höchststand von 36 %. Der gesamte kohlebefeuerte Kraftwerkspark wurde nach 1990 errichtet. In den Niederlanden wurde die Mitverbrennung von Biomasse in Steinkohlekraftwerken in der Vergangenheit subventioniert und wird immer noch praktiziert, ist aber nicht mehr Teil der Förderregelung für neue Anlagen. Ein kleiner Kernreaktor liefert einen konstanten Anteil von 3 % bis 4 % der Bruttoproduktion.

- Der Emissionsfaktor der Bruttostromerzeugung liegt mit 0,33 t CO_2 pro MWh um ein Drittel über dem Wert für die EU-28 im Jahr 2019. Während die Werte im Jahr 2010 ähnlich waren, ging der Emissionsfaktor der EU-28 stetig zurück, während der niederländische Emissionsfaktor mit der zunehmenden Kohleverstromung in den Niederlanden in den Jahren 2011 bis 2013 anstieg. Zwischen 2013 und 2019 sank der niederländische Emissionsfaktor nur um 22 %.

- Die Stromerzeugung aus erneuerbaren Energien machte 2019 nur 18 % der Gesamterzeugung aus. Wind- und Solarenergie haben seit 2013 stark zugenommen, während die Biomasse, die drittgrößte EE-Stromquelle in den Niederlanden, keine ähnliche Dynamik aufwies. Dennoch erwartet der niederländische NECP bis 2030 einen EE-Anteil an der Stromerzeugung von 73 %, der auf einen starken Ausbau der Offshore-Windkraft, aber auch der Onshore-Windkraft und der Photovoltaik erreicht werden soll.

- Die Niederlande sind ein wichtiges Transitland für Strom aus Deutschland und Norwegen in das Vereinigte Königreich. Gleichzeitig war das Land in den meisten Jahren des untersuchten Zeitraums ein Nettoimporteur von Strom. Der Umfang der Nettoimporte wurde durch die Überschusserzeugung aus Deutschland bestimmt.

- Es gibt einen Plan für den Ausstieg aus der Kohleverstromung, der die Abschaltung des letzten Kraftwerks bis Ende 2029 vorsieht. Die Niederlande haben außerdem einen CO_2-Mindestpreis für die Stromerzeugung eingeführt, der 2020 bei 12,30 Euro beginnt und bis 2030 schrittweise auf 31,90 Euro ansteigt.

Tabelle 6: Niederlande: Schlüsselindikatoren zum Stromsektor im Jahr 2019

	2019	% Veränderung im Vergleich zu 2013
	CO_2 Emissionen	
Gesamte CO_2-Emissionen im Jahr 2019 aus Activity Code 20 (Anteil an EU-28)	54 Mt CO_2 (6%)	-7%
Gesamte CO_2-Emissionen der Stromerzeugung[1] (Anteil Activity Code 20 im Land)	40 Mt CO_2 (74%)	-7%
Emissionsfaktor der Bruttostromerzeugung[2] (relativ zum EU-28-Durchschnitt)	0,33 t CO_2/MWh (138%)	-22%
	Bruttostromerzeugung	
Insgesamt (Anteil an EU-28 insgesamt)	121 TWh (4%)	19%
Netto-Stromimport	0 TWh	-98%
Anteil der Braunkohle an der Bruttostromerzeugung (Anteil an gesamten Brutto-BK-Verstromung in der EU-28)	0% (0%)	0%
Anteil erneuerbarer Energien an der Bruttoerzeugung (Ziel für 2030)[3]	18% (73%)	48%
	Installierte Kapazität	
Gesamte installierte BK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	0 GW (0%)	0%
Anteil der vor 1990 installierten BK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	0%	0%
Gesamte installierte SK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	5 GW (5%)	16%
Anteil der vor 1990 installierten SK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	0% (0%)	-100%

Anmerkung: [1] CO_2-Emissionen der Stromerzeugung auf Basis der in der EU-ETS-Datenbank des Öko-Instituts identifizierten Kraftwerke. [2] Emissionsfaktor berechnet auf Basis der CO_2-Emissionen der in der EU-ETS-Datenbank des Öko-Instituts identifizierten Kraftwerke und der von Ember (2020) gemeldeten Bruttostromerzeugung. [3] Gemäß Artikel 4 (2) der Verordnung (EU) 2018/1999 müssen die Mitgliedstaaten Informationen über ihren Beitrag zur Erreichung des verbindlichen Ziels der Union für erneuerbare Energien von mindestens 32 %, ausgedrückt als Anteil erneuerbarer Energien am Bruttoendenergieverbrauch, vorlegen. Sie tun dies in ihren NECP (Artikel 3 Absatz 2 Buchstabe b). Zusammen mit diesem Beitrag müssen sie auch über die geschätzten Zielpfade für den sektoralen Anteil erneuerbarer Energien am Endenergieverbrauch von 2021 bis 2030 in den Sektoren Strom, Wärme und Kälte sowie Verkehr berichten (siehe Anhang I der Verordnung (EU) 2018/1999, in dem die Struktur der NECP dargelegt ist)

Quelle: Eigene Darstellung basierend auf Ember (2020), EC n.d., Europe Beyond Coal (2022), und EEA (2021).

Polen

- 2019 emittierten Verbrennungs- und Energieanlagen (Activity Code 20) in Polen 145 Mio. t CO_2, womit Polen der zweitgrößte Emittent (15 %) in dieser Kategorie war. Die Stromerzeugung ist für 87 % der Emissionen in dieser Kategorie verantwortlich. Zwischen 2013 und 2019 sind die Emissionen der Stromerzeugung um 20 % zurückgegangen.

- Im Vergleich zur EU-28 hat Polen den höchsten Anteil an Kohle im Erzeugungsmix. Der Mix wird von der Steinkohleverstromung dominiert (48 %). Die Braunkohleverstromung macht weitere 26 % aus. Zwischen 2013 und 2019 ging die Braunkohleverstromung um 24 % zurück, während die Steinkohleverstromung nur um 6 % sank. Ein erheblicher Rückgang der Kohleverstromung ist vor allem im Jahr 2019 zu verzeichnen, wo sie durch eine verstärkte Erzeugung aus Erdgas und Importen aus dem Ausland ersetzt wurde. Mehr als zwei Drittel des kohlebefeuerten Kraftwerksparks wurden vor 1990 errichtet. Die gasbefeuerte Kapazität hat sich seit 2015 auf 1,8 GW erhöht; ihr Anteil an der Erzeugung nahm vor allem mit dem Anstieg des CO_2-Preises in den Jahren 2018 und 2019 zu.

- Der Anteil der Stromerzeugung aus erneuerbaren Energien ist mit 15 % im Jahr 2019 gering, obwohl er zwischen 2013 und 2019 um 43 % gestiegen ist. Der Plan, diesen Anteil bis 2030 auf 32 % zu erhöhen, stützt sich auf einen starken Ausbau der Offshore-Windkapazitäten in der Ostsee. Aufgrund der zentralen Rolle der Kohle bei der Stromerzeugung liegt der durchschnittliche Emissionsfaktor der Bruttostromerzeugung bei etwa 0,8 Mt CO_2 pro MWh, was mehr als dreimal so hoch ist wie der durchschnittliche Emissionsfaktor der EU-28 im Jahr 2019.

- Polen ist im mitteleuropäischen Elektrizitätssystem von einem Nettoexporteur zu einem Importeur geworden. Aufgrund seiner Lage im System bietet es auch Transitkapazitäten für die Erzeugung von Norddeutschland nach Süddeutschland in Zeiten hoher Winderzeugung im Norden (Ringflüsse). Diese Ringflüsse sind in den letzten Jahren mit dem Rückgang der einheimischen Erzeugung in Polen zurückgegangen.

- Die Kohleverstromung wird von Unternehmen dominiert, an denen der polnische Staat die Mehrheit hält. Ein Ausstieg aus der Kohleverstromung ist bis 2049 geplant, gilt aber nur für den Steinkohlebergbau. Polen hat immer wieder den Bau von Kernkraftwerken angekündigt, doch sind bisher keine konkreten Pläne in die Tat umgesetzt worden.

Tabelle 7: Polen: Schlüsselindikatoren zum Stromsektor im Jahr 2019

	2019	% Veränderung im Vergleich zu 2013
	CO_2 Emissionen	
Gesamte CO_2-Emissionen im Jahr 2019 aus Activity Code 20 (Anteil an EU-28)	145 Mt CO_2 (15%)	-15%
Gesamte CO_2-Emissionen der Stromerzeugung[1] (Anteil Activity Code 20 im Land)	127 Mt CO_2 (88%)	-20%
Emissionsfaktor der Bruttostromerzeugung[2] (relativ zum EU-28-Durchschnitt)	0,79 t CO_2/MWh (328%)	-19%
	Bruttostromerzeugung	
Insgesamt (Anteil an EU-28 insgesamt)	161 TWh (5%)	-1%
Netto-Stromimport	10 TWh	-323%
Anteil der Braunkohle an der Bruttostromerzeugung (Anteil an gesamten Brutto-BK-Verstromung in der EU-28)	26% (17%)	-24%
Anteil der Steinkohle an der Bruttostromerzeugung (Anteil an gesamten Brutto-SK-Verstromung in der EU-28)	48% (35%)	-6%
Anteil erneuerbarer Energien an der Bruttoerzeugung (Ziel für 2030)[3]	15% (32%)	43%
	Installierte Kapazität	
Gesamte installierte BK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	8,8 GW (16%)	-9%
Anteil der vor 1990 installierten BK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	73% (12%)	-7%
Gesamte installierte SK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	22 GW (22%)	9%
Anteil der vor 1990 installierten SK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	67% (29%)	-7%

Anmerkung: [1] CO_2-Emissionen der Stromerzeugung auf Basis der in der EU-ETS-Datenbank des Öko-Instituts identifizierten Kraftwerke. [2] Emissionsfaktor berechnet auf Basis der CO_2-Emissionen der in der EU-ETS-Datenbank des Öko-Instituts identifizierten Kraftwerke und der von Ember (2020) gemeldeten Bruttostromerzeugung. [3] Gemäß Artikel 4 (2) der Verordnung (EU) 2018/1999 müssen die Mitgliedstaaten Informationen über ihren Beitrag zur Erreichung des verbindlichen Ziels der Union für erneuerbare Energien von mindestens 32 %, ausgedrückt als Anteil erneuerbarer Energien am Bruttoendenergieverbrauch, vorlegen. Sie tun dies in ihren NECP (Artikel 3 Absatz 2 Buchstabe b). Zusammen mit diesem Beitrag müssen sie auch über die geschätzten Zielpfade für den sektoralen Anteil erneuerbarer Energien am Endenergieverbrauch von 2021 bis 2030 in den Sektoren Strom, Wärme und Kälte sowie Verkehr berichten (siehe Anhang I der Verordnung (EU) 2018/1999, in dem die Struktur der NECP dargelegt ist)

Quelle: Eigene Darstellung basierend auf Ember (2020), EC n.d., Europe Beyond Coal (2022), und EEA (2021).

Rumänien

- 2019 emittierten Verbrennungs- und Energieanlagen (Activity Code 20) in Rumänien 22 Mio. t CO_2, was Rumänien zum zehntgrößten Emittenten (2 %) in dieser Kategorie machte. Die Stromerzeugung ist für 81 % der Emissionen in dieser Kategorie verantwortlich. Zwischen 2013 und 2019 sind die Emissionen der Stromerzeugung um 25 % zurückgegangen.
- Rumänien hat einen vielfältigen Erzeugungsmix. Der Anteil der Braunkohleverstromung an der Stromerzeugung ist von 36 % im Jahr 2005 auf 22 % im Jahr 2019 gesunken. Steinkohle hat 2019 einen Anteil von 2 %, während 2013 die Erzeugung 0,4 TWh oder 65 % weniger betrug. Sowohl Steinkohle als auch Braunkohle wird aus heimischen Bergwerken geliefert. Der gesamte kohlebefeuerte Kraftwerkspark wurde vor 1990 errichtet. Die Kernenergie wurde 2007 ausgebaut und trägt seither 20 % zur Gesamterzeugung bei. Die Stromerzeugung aus Erdgas trug im Zeitraum 2005 bis 2019 rund 15 % zur Gesamterzeugung bei.
- Der Anteil der Stromerzeugung aus erneuerbaren Energien an der Gesamterzeugung lag im Jahr 2019 bei 41 %. Wasserkraft ist eine traditionelle EE-Stromquelle in Rumänien, die 15 bis 20 TWh erzeugt und 2019 63 % des EE-Stromanteils ausmachte. Die Wind- und Solarenergie wurde zwischen 2010 und 2015 rasch ausgebaut und stagniert seitdem.
- Der Emissionsfaktor der Bruttostromerzeugung liegt mit 0,30 t CO_2 pro MWh etwa 30 % über dem Wert für die EU-28 im Jahr 2019. Mit abnehmender Braunkohleverstromung und steigendem EE-Stromangebot ist der Emissionsfaktor seit 2013 um mehr als 25 % gesunken.
- Rumänien war ein CO_2-Exporteur im europäischen Stromsystem, insbesondere in Zeiten hoher Wasserkrafterzeugung und zunehmender Einspeisung von Wind- und Solarstrom. Aufgrund höherer CO_2-Preise und geringer Wasserkrafterzeugung wurde Rumänien 2019 zum Stromimporteur.
- Für 2032 ist ein Kohleausstieg geplant. Parallel dazu ist geplant, die bestehenden Kernkraftwerke zu modernisieren und bis 2031 ein neues zu bauen.

Tabelle 8: Rumänien: Schlüsselindikatoren zum Stromsektor im Jahr 2019

	2019	% Veränderung im Vergleich zu 2013
	CO_2 Emissionen	
Gesamte CO_2-Emissionen im Jahr 2019 aus Activity Code 20 (Anteil an EU-28)	22 Mt CO_2 (2%)	-27%
Gesamte CO_2-Emissionen der Stromerzeugung[1] (Anteil Activity Code 20 im Land)	18 Mt CO_2 (81%)	-25%
Emissionsfaktor der Bruttostromerzeugung[2] (relativ zum EU-28-Durchschnitt)	0,3 t CO_2/MWh (124%)	-28%
	Bruttostromerzeugung	
Insgesamt (Anteil an EU-28 insgesamt)	61 TWh (2%)	4%
Netto-Stromimport	1 TWh	-174%
Anteil der Braunkohle an der Bruttostromerzeugung (Anteil an gesamten Brutto-BK-Verstromung in der EU-28)	22% (5%)	-19%
Anteil der Steinkohle an der Bruttostromerzeugung (Anteil an gesamten Brutto-SK-Verstromung in der EU-28)	2% (1%)	193%
Anteil erneuerbarer Energien an der Bruttoerzeugung (Ziel für 2030)[3]	41% (49%)	19%
	Installierte Kapazität	
Gesamte installierte BK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	4,6 GW (9%)	-14%
Anteil der vor 1990 installierten BK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	100% (8%)	0%
Gesamte installierte SK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	1,3 GW (1%)	0%
Anteil der vor 1990 installierten SK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	100% (2%)	0%

Anmerkung: [1] CO_2-Emissionen der Stromerzeugung auf Basis der in der EU-ETS-Datenbank des Öko-Instituts identifizierten Kraftwerke. [2] Emissionsfaktor berechnet auf Basis der CO_2-Emissionen der in der EU-ETS-Datenbank des Öko-Instituts identifizierten Kraftwerke und der von Ember (2020) gemeldeten Bruttostromerzeugung. [3] Gemäß Artikel 4 (2) der Verordnung (EU) 2018/1999 müssen die Mitgliedstaaten Informationen über ihren Beitrag zur Erreichung des verbindlichen Ziels der Union für erneuerbare Energien von mindestens 32 %, ausgedrückt als Anteil erneuerbarer Energien am Bruttoendenergieverbrauch, vorlegen. Sie tun dies in ihren NECP (Artikel 3 Absatz 2 Buchstabe b). Zusammen mit diesem Beitrag müssen sie auch über die geschätzten Zielpfade für den sektoralen Anteil erneuerbarer Energien am Endenergieverbrauch von 2021 bis 2030 in den Sektoren Strom, Wärme und Kälte sowie Verkehr berichten (siehe Anhang I der Verordnung (EU) 2018/1999, in dem die Struktur der NECP dargelegt ist)

Quelle: Eigene Darstellung basierend auf Ember (2020), EC n.d., Europe Beyond Coal (2022), und EEA (2021).

Spanien

- 2019 emittierten Verbrennungs- und Energieanlagen (Activity Code 20) in Spanien 55 Mio. t CO_2, womit Spanien der fünftgrößte Emittent (6 %) in dieser Kategorie war. Die Stromerzeugung ist für 75 % der Emissionen in dieser Kategorie verantwortlich. Zwischen 2013 und 2019 sind die Emissionen der Stromerzeugung um 31 % zurückgegangen.

- Spanien hat einen vielfältigen Erzeugungsmix. Die gasgefeuerte Erzeugung machte 2019 etwa 30 % der Bruttostromerzeugung aus. Kohle hatte 2019 einen Anteil von 4 %, womit ihre Erzeugung seit 2013 um mehr als zwei Drittel zurückgegangen ist. Alle Braunkohlekraftwerke und mehr als 80 % der Steinkohlekraftwerke wurden vor 1990 errichtet. Der Anteil der Kernenergie liegt konstant bei 20 %. Die Stromerzeugung aus anderen fossilen Energieträgern (z. B. Abgase aus der Raffinerie- und Stahlerzeugung) hat sich zwischen 2005 und 2013 halbiert und macht 2019 nur noch 6 % der Gesamterzeugung aus.

- Der Emissionsfaktor der Bruttostromerzeugung liegt mit 0,15 t CO_2 pro MWh 40 % unter dem Wert für die EU-28. Mit der sinkenden Erzeugung aus Kohle und anderen fossilen Brennstoffen ist der Emissionsfaktor seit 2013 um fast 30 % gesunken.

- Im Jahr 2019 betrug der Anteil der Stromerzeugung aus erneuerbaren Energien an der Gesamterzeugung 37 %. Wasserkraft ist eine traditionelle EE-Stromquelle in Spanien mit starken Schwankungen in der Erzeugung zwischen 21 TWh und 46 TWh. Die Erzeugung aus Photovoltaik und Windkraft erlebte zwischen 2005 und 2013 einen Boom. Aufgrund einer geänderten Regulierung ist der EE-Strom-Ausbau seit 2014 zum Stillstand gekommen, und der EE-Strom-Anteil ist von seinem Höchststand von 41 % im Jahr 2013 aufgrund eines starken Rückgangs der Stromerzeugung aus Wasserkraft zwischen 2013 und 2019 zurückgegangen. Im Jahr 2019 hat die Zahl der Anlagen wieder zugenommen. Die ehrgeizigen Pläne zur Erhöhung des EE-Stromanteils auf 74 % bis 2030 durch einen neuen Ausbau der Wind- und Solarkapazitäten werden durch ein neues Förderregime unterstützt.

- Spanien hat seine Position im südwesteuropäischen Stromsystem von einem Nettoexporteur bis 2015 zu einem Nettoimporteur seit diesem Jahr geändert.

- Für 2030 ist ein Kohleausstieg geplant; der letzte Braunkohleblock wurde 2020 stillgelegt. Der Ausstieg aus der Kernenergie soll zwischen 2025 und 2035 erfolgen, was eine Laufzeitverlängerung über die 40-Jahresgrenze hinaus bedeutet. Ein Kapazitätsmarkt soll dazu beitragen, dass bis 2030 insgesamt 20 GW an Speicherkapazität installiert werden.

Tabelle 9: Spanien: Schlüsselindikatoren zum Stromsektor im Jahr 2019

	2019	% Veränderung im Vergleich zu 2013
	CO_2 Emissionen	
Gesamte CO_2-Emissionen im Jahr 2019 aus Activity Code 20 (Anteil an EU-28)	55 Mt CO_2 (6%)	-22%
Gesamte CO_2-Emissionen der Stromerzeugung[1] (Anteil Activity Code 20 im Land)	41 Mt CO_2 (75%)	-31%
Emissionsfaktor der Bruttostromerzeugung[2] (relativ zum EU-28-Durchschnitt)	0,15 t CO_2/MWh (63%)	-27%
	Bruttostromerzeugung	
Insgesamt (Anteil an EU-28 insgesamt)	273 TWh (8%)	-4%
Netto-Stromimport	7 TWh	-196%
Anteil der Braunkohle an der Bruttostromerzeugung (Anteil an gesamten Brutto-BK-Verstromung in der EU-28)	0,2% (0,2%)	-
Anteil der Steinkohle an der Bruttostromerzeugung (Anteil an gesamten Brutto-SK-Verstromung in der EU-28)	4% (5%)	-74%
Anteil erneuerbarer Energien an der Bruttoerzeugung (Ziel für 2030)[3]	37% (74%)	-8%
	Installierte Kapazität	
Gesamte installierte BK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	1,1 GW (2%)	0%
Anteil der vor 1990 installierten BK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	100% (2%)	0%
Gesamte installierte SK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	9 GW (9%)	-14%
Anteil der vor 1990 installierten SK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	83% (8%)	-9%

Anmerkung: [1] CO_2-Emissionen der Stromerzeugung auf Basis der in der EU-ETS-Datenbank des Öko-Instituts identifizierten Kraftwerke. [2] Emissionsfaktor berechnet auf Basis der CO_2-Emissionen der in der EU-ETS-Datenbank des Öko-Instituts identifizierten Kraftwerke und der von Ember (2020) gemeldeten Bruttostromerzeugung. [3] Gemäß Artikel 4 (2) der Verordnung (EU) 2018/1999 müssen die Mitgliedstaaten Informationen über ihren Beitrag zur Erreichung des verbindlichen Ziels der Union für erneuerbare Energien von mindestens 32 %, ausgedrückt als Anteil erneuerbarer Energien am Bruttoendenergieverbrauch, vorlegen. Sie tun dies in ihren NECP (Artikel 3 Absatz 2 Buchstabe b). Zusammen mit diesem Beitrag müssen sie auch über die geschätzten Zielpfade für den sektoralen Anteil erneuerbarer Energien am Endenergieverbrauch von 2021 bis 2030 in den Sektoren Strom, Wärme und Kälte sowie Verkehr berichten (siehe Anhang I der Verordnung (EU) 2018/1999, in dem die Struktur der NECP dargelegt ist)

Quelle: Eigene Darstellung basierend auf Ember (2020), EC n.d., Europe Beyond Coal (2022), und EEA (2021).

Vereinigtes Königreich

- Im Jahr 2019 emittierten Verbrennungs- und Energieanlagen (Activity Code 20) im Vereinigten Königreich 81 Mio. t CO_2 und waren damit der viertgrößte Emittent (9 %) in dieser Kategorie. Die Stromerzeugung ist nur für 59 % der Emissionen in dieser Kategorie verantwortlich. Zwischen 2013 und 2019 sind die Emissionen der Stromerzeugung um 67 % zurückgegangen.
- Der Stromerzeugungsmix des Vereinigten Königreichs wird von der gasgefeuerten Erzeugung dominiert, die 2019 einen Anteil von 40 % an der Stromerzeugung hat, gegenüber 27 % im Jahr 2013. Steinkohle hat 2019 einen Anteil von 2 %, während die Erzeugung 2013 mit 130 TWh 18-mal so hoch war. Aufgrund der strengeren EU-Luftqualitätsvorschriften und der Einführung eines CO_2-Mindestpreises im Jahr 2013 wurden viele kohlebefeuerte Blöcke stillgelegt, anstatt nachgerüstet zu werden oder auf Biomassefeuerung umgestellt. Der gesamte verbleibende Kohlekraftwerkspark wurde vor 1990 errichtet. Die Kernenergie liefert etwa 20 % der Gesamtproduktion.
- Der Anteil der Stromerzeugung aus erneuerbaren Energien an der Gesamterzeugung lag 2019 bei 38 %, was einem Anstieg von 143 % seit 2013 entspricht. Der rasche Ausbau der Wind- und Solarkapazitäten begann 2011; die Erzeugung aus Biomasse wird seit 2013 ausgebaut.
- Der Emissionsfaktor der Bruttostromerzeugung liegt mit 0,15 t CO_2 pro MWh etwa 40 % unter dem Wert für die EU-28 im Jahr 2019. Durch den Rückgang der Kohleverstromung und die zunehmende Einspeisung von EE-Strom ist der Emissionsfaktor seit 2013 um 64 % gesunken.
- Das Vereinigte Königreich ist ein wichtiger Stromimporteur im europäischen Stromsystem. Die Importe aus Frankreich, den Niederlanden und Belgien machen 6 % des Bruttostromverbrauchs aus. Eine neue Verbindungsleitung mit Norwegen wurde im Oktober 2021 in Betrieb genommen.
- Ein Kohleausstieg ist für Ende 2024 geplant. Parallel dazu befindet sich das 3,3-GW-Kernkraftwerk Hinkley Point C im Bau. Nach mehreren Verzögerungen soll nun der erste Block in 2031 in Betrieb gehen. Das Kraftwerk wird über eine flexible Marktprämie (Contract for Difference) finanziert.

Tabelle 10: Vereinigtes Königreich: Schlüsselindikatoren zum Stromsektor im Jahr 2019

	2019	% Veränderung im Vergleich zu 2013
	CO_2 Emissionen	
Gesamte CO_2-Emissionen im Jahr 2019 aus Activity Code 20 (Anteil an EU-28)	81 Mt CO_2 (9%)	-54%
Gesamte CO_2-Emissionen der Stromerzeugung[1] (Anteil Activity Code 20 im Land)	48 Mt CO_2 (59%)	-67%
Emissionsfaktor der Bruttostromerzeugung[2] (relativ zum EU-28-Durchschnitt)	0,15 t CO_2/MWh (63%)	-64%
	Bruttostromerzeugung	
Insgesamt (Anteil an EU-28 insgesamt)	322 TWh (10%)	-10%
Netto-Stromimport	22 TWh	53%
Anteil der Braunkohle an der Bruttostromerzeugung (Anteil an gesamten Brutto-BK-Verstromung in der EU-28)	0% (0%)	0%
Anteil der Steinkohle an der Bruttostromerzeugung (Anteil an gesamten Brutto-SK-Verstromung in der EU-28)	2% (3%)	-94%
Anteil erneuerbarer Energien an der Bruttoerzeugung (Ziel für 2030)[3]	38% (50% - 75%)	143%
	Installierte Kapazität	
Gesamte installierte BK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	0 GW (0%)	0%
Anteil der vor 1990 installierten BK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	0%	0%
Gesamte installierte SK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	12,4 GW (13%)	-55%
Anteil der vor 1990 installierten SK-gefeuerte Kapazität (Anteil an der gesamten EU-28)	100% (12%)	0%

Anmerkung: [1] CO_2-Emissionen der Stromerzeugung auf Basis der in der EU-ETS-Datenbank des Öko-Instituts identifizierten Kraftwerke. [2] Emissionsfaktor berechnet auf Basis der CO_2-Emissionen der in der EU-ETS-Datenbank des Öko-Instituts identifizierten Kraftwerke und der von Ember (2020) gemeldeten Bruttostromerzeugung. [3] Gemäß Artikel 4 (2) der Verordnung (EU) 2018/1999 müssen die Mitgliedstaaten Informationen über ihren Beitrag zur Erreichung des verbindlichen Ziels der Union für erneuerbare Energien von mindestens 32 %, ausgedrückt als Anteil erneuerbarer Energien am Bruttoendenergieverbrauch, vorlegen. Sie tun dies in ihren NECP (Artikel 3 Absatz 2 Buchstabe b). Zusammen mit diesem Beitrag müssen sie auch über die geschätzten Zielpfade für den sektoralen Anteil erneuerbarer Energien am Endenergieverbrauch von 2021 bis 2030 in den Sektoren Strom, Wärme und Kälte sowie Verkehr berichten (siehe Anhang I der Verordnung (EU) 2018/1999, in dem die Struktur der NECP dargelegt ist)

Quelle: Eigene Darstellung basierend auf Ember (2020), EC n.d., Europe Beyond Coal (2022), und EEA (2021).

1 Introduction: Motivation and country selection

The dynamic development of an integrated and liberalized European electricity market, a heterogeneous endowment in generation fleets in terms of generation technology and primary fuel and business model, the fast but varied uptake of renewable energies have all co-developed in an environment of fluctuating primary fuel prices and an emerging, but for most of the time very modest, CO_2 price in the EU ETS. This report aims to shed light into this co-evolution. Combustion installations summarized under Activity Code 20 in the EU ETS comprised more than 64 % of total emissions covered by the EU ETS, hence making up the single largest covered activity. According to our research, more than 81 % of these installations are electric and combined heat and power (CHP) plants. Due to the interconnectedness, the difference in emission intensity of the different fuels and their configuration in a competitive marginal cost pricing market, installations under Activity Code 20 also had a large potential for a cleaner dispatch of generation units initiated by the pricing signal of the EU ETS.

This report provides an in-depth analysis of the electricity sector since the introduction of the EU ETS in 2005. It allows key drivers behind the development in capacities, generation levels and emissions to be identified. It thereby provides key information from past developments which form the basis for future projections and the design of tailored policy instruments.

The report provides information on the European level and for 10 selected European countries in the form of brief fact sheets. The country selection was based on emission levels and trends (EU ETS, Activity Code 20, EEA 2021), share of fuel type in total gross generation (Ember 2020), emissions intensity, calculated by dividing emissions from identified electricity generators by gross electricity generation (EU ETS, Activity Code 20, EEA 2021, own assignment based on EC n.d. and Ember 2020), electricity trade intensity in physical units (ENTSO-E and national TSOs), and electricity consumption (Ember 2020). In order to provide a broad picture of national trends in the EU, the following countries were chosen for fact sheets: the Czech Republic, Estonia, France, Germany, Italy, the Netherlands, Poland, Romania, Spain and the United Kingdom. An overview of the countries chosen (in bold) and further EU28 countries can be found in the table below. The selected countries together account for 84 % of EU-28 emissions of electricity generators and 77 % of total (gross) electricity generation. The selection covers countries from All regions of the EU, different sizes and emission intensity of electricity generation. Estonia and Poland are examples of countries with high emission intensity; France, in contrast, has low specific emissions. Furthermore, care was taken to choose different shares of coal-based electricity generation as well as renewable shares.

Table 11 Overview of emissions and electricity generation of European countries

	CO_2 emissions from electricity producers [Mt. CO_2-e]	Total electricity generation [TWh]	Emission factor of gross electricity generation [kg CO_2/MWh]	Coal share in electricity generation	Renewable share in electricity generation
Austria	6	73	76	2%	78%
Belgium	11	92	125	0%	22%
Bulgaria	21	45	472	42%	14%
Croatia	3	12	215	11%	61%
Cyprus	3	5	656	0%	9%
Czech Republic	**45**	**86**	**517**	**43%**	**13%**
Denmark	4	31	141	15%	84%
Estonia	**6**	**6**	**992**	**0%**	**22%**
Finland	10	68	152	11%	46%
France	**17**	**570**	**31**	**1%**	**21%**
Germany	**234**	**605**	**387**	**28%**	**40%**
Greece	25	52	484	24%	31%
Hungary	9	33	283	14%	11%
Ireland	8	30	271	14%	34%
Italy	**72**	**289**	**251**	**6%**	**40%**
Latvia	1	7	187	0%	48%
Lithuania	0	4	77	0%	82%
Luxembourg	0	2	33	0%	87%
Malta	1	2	450	0%	10%
Netherlands	**40**	**121**	**331**	**14%**	**18%**
Poland	**127**	**161**	**786**	**74%**	**15%**
Portugal	10	54	176	11%	54%
Romania	**18**	**61**	**297**	**24%**	**41%**

	CO_2 emissions from electricity producers [Mt. CO_2-e]	Total electricity generation [TWh]	Emission factor of gross electricity generation [kg CO_2/MWh]	Coal share in electricity generation	Renewable share in electricity generation
Slovakia	3	28	95	8%	27%
Slovenia	4	16	266	28%	32%
Spain	**41**	**273**	**150**	**4%**	**37%**
Sweden	3	171	18	0%	58%
United Kingdom	**48**	**322**	**150**	**2%**	**38%**
EU-28	772	3219	240	15%	35%

Note: CO_2 emissions from electricity producers based on power plants identified in Oeko-Institut's EU ETS database. Emission factor calculated based on CO_2 emissions by power plants and gross electricity production reported by Ember (2020).
Source: Own table based on Ember (2020), EC n.d., and EEA (2022).

2 Power sector covered by the EU ETS

2.1 Key messages

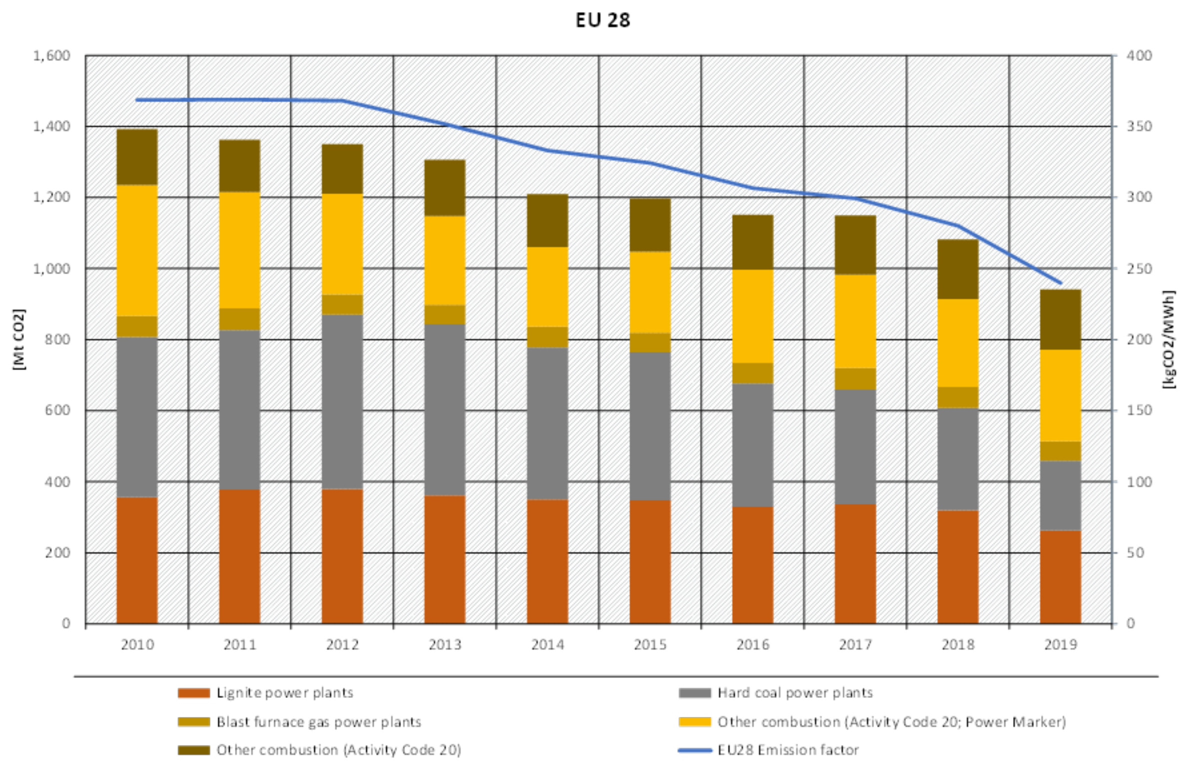
- The EU-28 is a highly interconnected energy market with a wide variety of generation technologies and primary energy sources that are employed in the different countries. Member States' generation structure depends on locally available resources (fossil fuels: Germany, Poland, the Czech Republic, Bulgaria, Romania, Estonia, hydro: Norway, Spain, Italy, France) or historical trade relations for natural gas imports such as Italy and Spain, and the role of nuclear power. The role of renewable energies also varies greatly, which is due to natural conditions, but above all to the different regulatory environments and the corresponding support approaches and levels.
- The different power plant fleets result in very different emission factors of the electricity mix and thus also different sensitivities to a CO_2 price. Changes in total emissions are driven by electricity demand, renewable generation, and the fossil generation mix. The CO_2 price has the potential to influence the fossil mix by giving geneation with lower CO_2 intensity an economic advantage over generation with higher specific emissions and thus higher CO_2 costs. However, adjustment effects take place in the interconnected Central European power grid and thus beyond national borders.
- At the EU-28 level, emissions fell by 33 % between 2013 and 2019, with the largest decline between 2018 and 2019 driven by reductions in lignite and hard coal generation in Germany, Poland, and the Czech Republic, among others.
- There are several examples which show that the CO_2 price has influenced the dispatch and thereby contributed to emission reductions: GHG-intense electricity generation using oil shale in Estonia has dropped as CO_2-prices rose; the CO_2 price in combination with low natural gas prices has made natural gas-fired generation more economically viable than some hard coal-fired capacities in Germany; and in France, the closure of coal-fired power plants coincides with the cessation of free allocation and the strengthening of air pollution regulations.
- Most EU-28 countries plan to phase out coal by 2030 or earlier. Germany, the Czech Republic, Romania and Bulgaria plan to phase out coal between 2030 and 2040; only Poland is currently planning to do so in 2049.
- The targets for the expansion of renewables vary widely. While Germany, according to current plans, is aiming for a share of 80 % of gross electricity consumption in 2030, the target in the Czech Republic comprises only a 16.9 % share.
- Countries with a large thermal power plant fleet like Germany, Poland and the Czech Republic (nuclear, lignite and hard coal), France (nuclear) or Estonia (oil shale) show comparably lower wholesale prices than countries in which generation is dominated by gas-fired units (like Italy, the UK or Spain). Seasonal demand differs across Europe: southern countries like Spain, Italy and Greece have their demand peak in the summer, when

electricity is needed for cooling. Northern countries tend to have their demand peak and hence also their electricity price peak in the winter, when electricity is required for lighting and also broadly used for heating (the latter is true especially in France or the UK).

2.2 Emission trends in the EU ETS (combustion installations)

Emissions from the Activity Code 20 (combustion installations) have declined sharply in recent years in the countries covered by the EU ETS. Figure 3 shows the emission trends of combustion installations in the EU-28 between 2010 and 2019 based on EC n.d. data and our own research. Power plants are differentiated by fuel in the figure.

Figure 3: EU-28: Emission trends in Activity Code 20



Note: Data for Croatia were extrapolated for the years 2010-2012 using total GHG inventory data as a proxy for emission trends. Emissions in the category: other combustion (Activity Code 20; Power Marker) are calculated using the deduction method: All emissions with Power Marker minus emissions from lignite and hard coal-fired power plants minus emissions from blast furnace gas power plants.

Source: Own illustration based on data from Europe Beyond Coal (2022), EEA (2021), and own assignment based on EC n.d..

Lignite and hard coal-fired power plants accounted for about 65 % of all emissions covered by Activity Code 20 in 2013. This percentage decreased to 47 % in 2019. Emissions from lignite power plants amounted to approx. 260 Mt CO_2 in 2019, corresponding to a reduction of 27 % compared to 2013. Emissions from hard coal power plants amounted to 200 Mt CO_2 in 2019, corresponding to a reduction of 59 % compared to 2013. During the same period, emissions from blast furnace power plants remained unchanged at 53 Mt CO_2. Emissions from the category "Other Combustion (activity Code 20; Power Marker)," which are natural gas-fired, oil-fired and other power plants only saw a 3 % increase from 252 Mt CO_2 in 2013 to 260 Mt CO_2 in 2019.

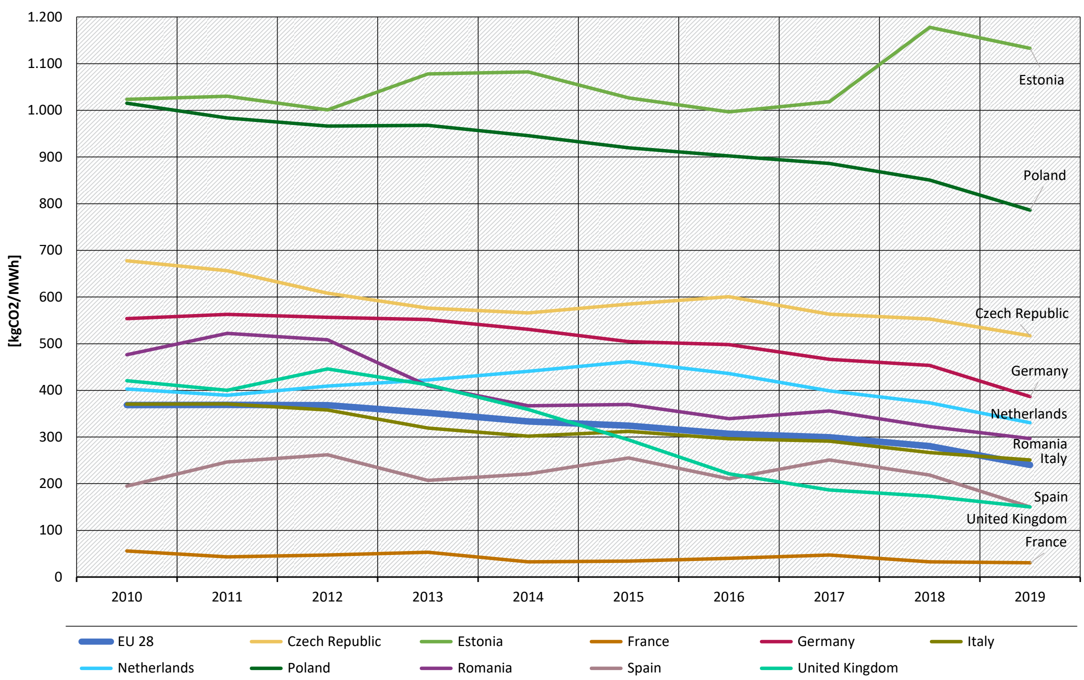
However, the strongest decline occurred between 2018 and 2019: within one year, emissions from power plants decreased by 142 Mt CO_2. Hard coal power plants mostlycontributed to this abatement (91 Mt CO_2 from hard coal power plants). Lignite-fired power plants contributed 57 Mt CO_2. Emissions from other power plants (mainly natural gas-fired) increased by about 10 Mt CO_2 from 2018 to 2019.

The category "Other combustion (Activity Code 20)" includes the non-electricity generating installations and remained stable between 2010 and 2019.

Figure 3 also includes the emission factor of gross electricity production in the EU-28. It declined from 370 kg CO_2/MWh in 2010 to 240 kg CO_2/MWh in 2019.

Figure 4 shows the development of emission factors for the EU-28 and for the ten countries selected for this study in direct comparison between 2010 and 2019. Estonia, Poland, the Czech Republic, Germany, the Netherlands and Romania had more emission-intensive electricity generation than the EU-28 average throughout the period. The trend of Italy's emission factors is quite similar to that of the EU-28, while the UK changed from having higher emission factors than the EU average until 2014 to lower emission factors from 2015 onwards. The emission factors of Spain and France were always below the EU-28 values in the period considered. The following chapters examine more closely the reasons for these very different emission factor levels.

Figure 4: Emission factor of gross electricity production in EU-28 and selected countries



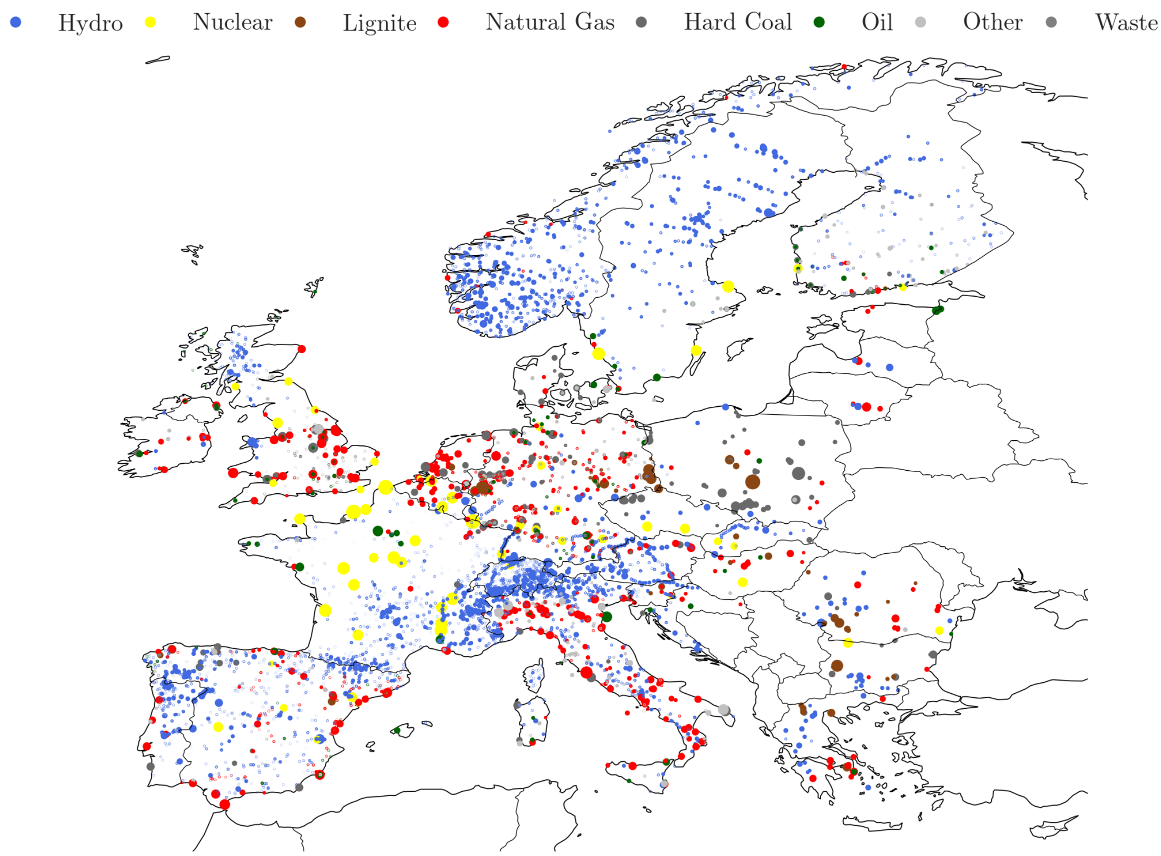
Note: Emission factor calculated based on CO_2 emissions by power plants identified in Oeko-Institut's EU ETS database and gross electricity production reported by Ember (2020). It might differ from the values given under EEA (2022).
Source: Own illustration based on data from Ember (2020), and own assignment based on EC n.d. for individual countries and EEA (2022) for EU-28.

2.3 Capacity trends

2.3.1 Existing capacities

Figure 5 shows the distribution of large-scale power-generation units in the EU-28, Switzerland and Norway. It highlights the diversity in generation technologies and primary energy sources that are employed in the different countries. The primary energy source was historically predetermined by the endowment in natural resources and primary trade partnerships. This is most obvious for hydro power, which can be found in mountainous regions in countries such as France, Switzerland, Germany, Austria and Italy, Portugal, Spain and Norway. The same is true for lignite-fired generation in Germany, Poland, the Czech Republic, Greece, Bulgaria and Romania. Generation is dominated by mine-mouth power plants ensuring that this energy carrier with low energy content is not transported over long distances.

Figure 5: Distribution of large-scale power generation units in the EU, UK, Switzerland and Norway



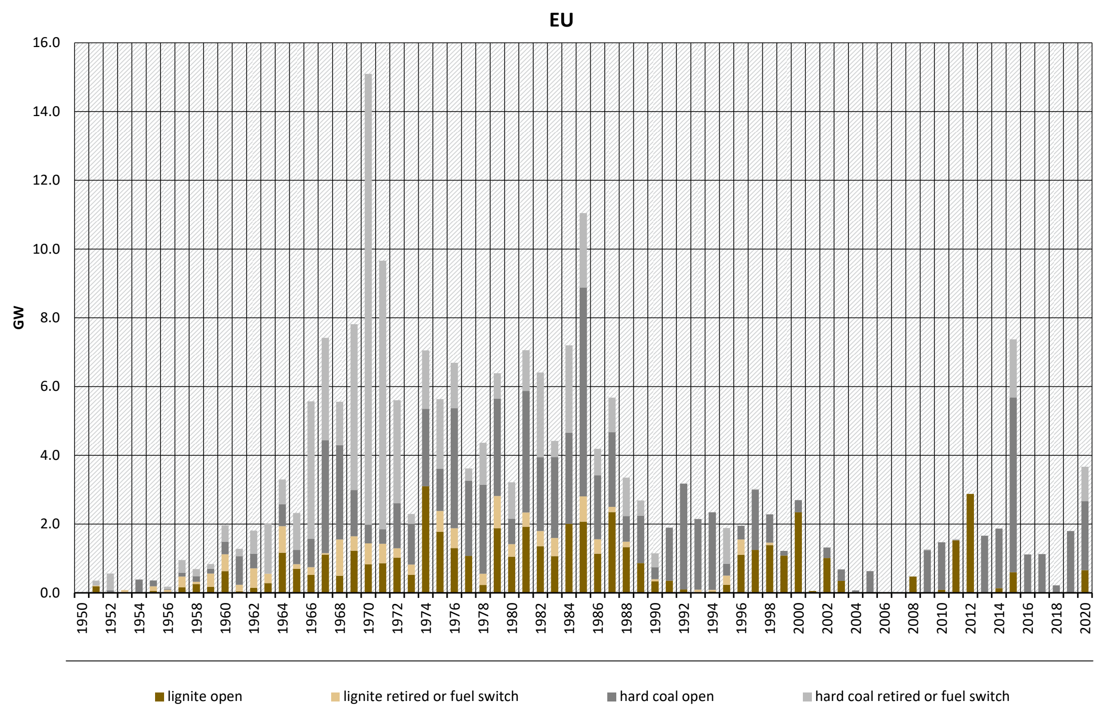
Source: Gotzens et al. (2019).

The heritage of hard coal-fired generation is less straight forward. Like with lignite, hard coal-fired power plants were initially built close to hard coal deposits, e.g. in the English and Welsh coal fields in the UK or near the coal field in the Ruhr area in Germany, and Silesia in Poland. In the 1970s, hard coal became an internationally traded commodity, and since then domestic coal production has increasingly competed with international markets. Nowadays, coal production in most European production regions is not competitive with international markets and coal-fired power plants are located along the shores and big rivers for easy access to international markets. Hard-coal-fired generation capacities can be found in countries which used to exploit own hard coal deposits (such as Germany and the UK), countries with easy access to international seaborne commodity trade (such as Portugal, the Netherlands and Italy) or countries that still hold on to domestic production like Poland or Romania. In view of achieving climate targets, more and more countries have closed down coal power plants or developed plans to phase out coal, aiming at a drastic reduction of the corresponding capacities in the years ahead. Part of this development is also the conversion of coal-fired power plants into biomass-fired plants, as is the case in, for example, Denmark (Robb 2019), the Netherlands (Bioenergy International 2021), or the UK (Electric Insights 2021).

A transition story can also be told for natural gas-fired units. Traditionally, they were located in countries with their own production such as the UK and the Netherlands or in those countries that could secure long-term supply with strategic trade partners via pipeline connections: Spain, Italy, Germany, and the former countries of the Eastern bloc. Since the liquefied natural gas technology (LNG) has made international natural gas trade less dependent on pipeline infrastructure, countries with access to international seaborne trade, such as Greece, Italy, Spain but also the Baltic states and Poland, are building gas-fired capacities or at least have diversified their supplies. A particularity in the European electricity system is the French generation fleet. Here, nuclear power contributes 70-80 % to total electricity generation.

Figure 6 shows the age structure of coal-fired power plants in the EU-28, sorted by commissioning year between 1950 and 2020. Capacities that are retired today or have undergone a fuel switch are shown in paler colours. Most coal-fired power plants were built in the 1960s to 1980s with a peak of 150 GW commissioned in 1970. The majority of the hard coal power plants built in the 1960s and early 1970s are retired today.

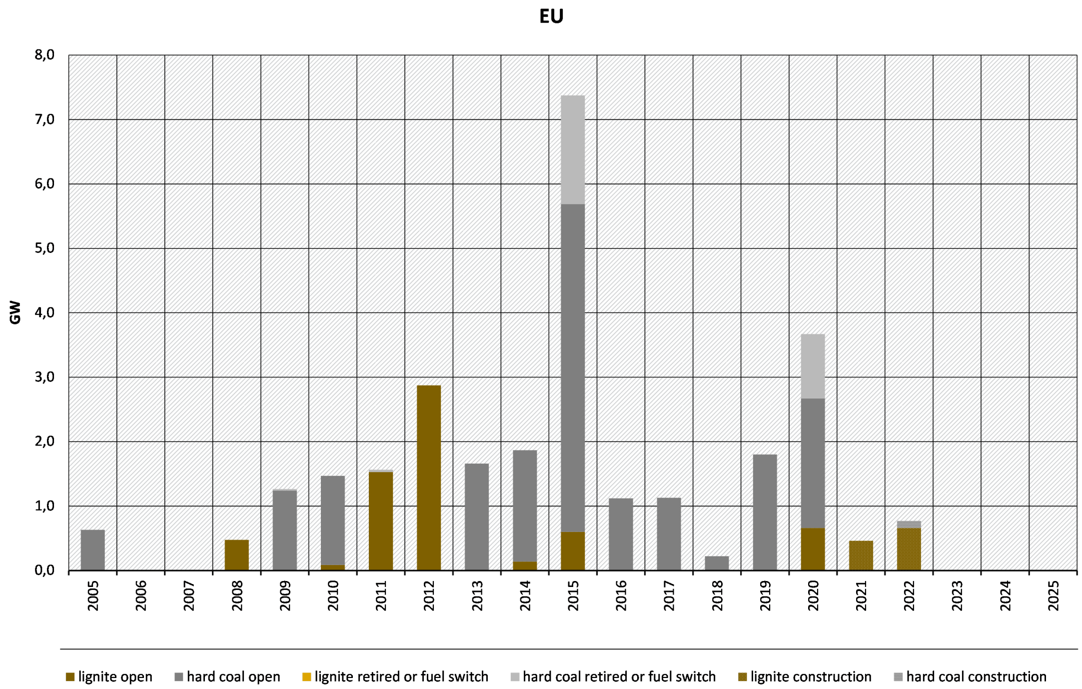
Figure 6: EU-28: Age structure of lignite and hard coal power plants sorted by year of commissioning



Source: Own illustration based on data from Europe Beyond Coal (2022).

Hard coal power plant investments continued during the early 1990s while new lignite power plants came online in the second half of the 1990s. There were lower investment activities during the early 2000s. More new coal-fired power plants came online continuously every year again since 2008.

Figure 7: EU-28: New lignite and hard coal power plants since 2005, including plants under construction sorted by year of commissioning



Source: Own illustration based on data from Europe Beyond Coal (2022).

Figure 7 takes a closer look at new coal-fired power plants built since the beginning of the EU ETS in 2005. These coal power plants were built in six countries:

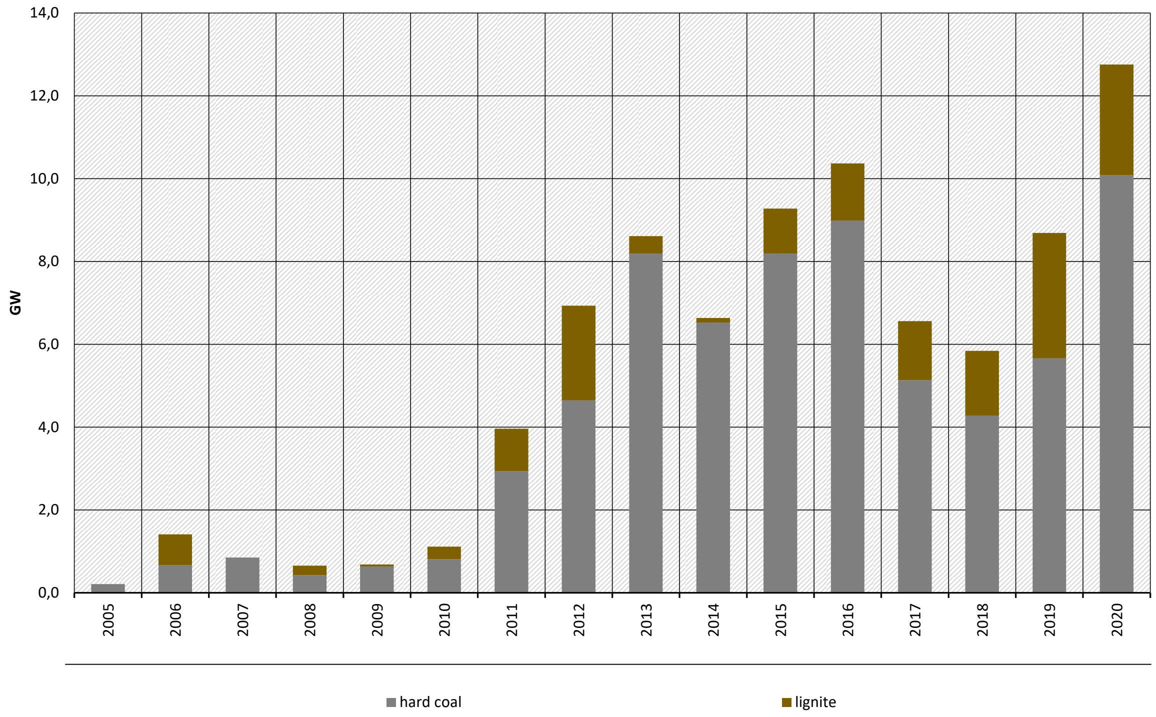
Almost half of the new hard coal units were built in Germany (8.9 GW) and more than a quarter in Poland (5.7 GW). Number three were the Netherlands (3.7 GW) and Italy was number four (2.3 GW). Small additions were made in Bulgaria and France.

Also in the case of lignite, Germany accounts again for the largest share, 40 % of all new lignite blocks (2.9 GW) were built there. Poland again makes up for a quarter of new lignite units. The remaining share is almost equally divided between the Czech Republic, Bulgaria, Greece and Slovenia. The two lignite blocks under construction are in Poland and Greece, the small hard coal block under construction is situated in Poland.

Figure 8 shows the retired coal-fired plants in the EU-28 since 2005 sorted by retirement date. Most retirements took place since 2011, when 4 GW were taken out of the system. This number increased to 10 GW in 2010 and peaked to more than 12 GW being decommissioned in 2020.

The combination of the ETS with further policies has triggered these retirements (Abrell et al. 2020). In general, the effect of the ETS price is higher for older power plants than for new ones, because the lower efficiencies of older plants lead to higher costs not only for fuel but also for CO_2 certificates.

Figure 8: EU-28: Retired coal-fired plant capacities in the EU-28 (including fuel switch) sorted by retirement date



Source: Own illustration based on data from Europe Beyond Coal (2022).

Most of the retired hard coal-fired power plants were decommissioned in the UK, as can be seen in Figure 9. Here the same capacities are shown as in Figure 6, now grouped by country. The chart also includes power plants that have already been decommissioned (or converted to other fuels) to show the general tendency towards coal-fired power plants in different countries over recent decades.

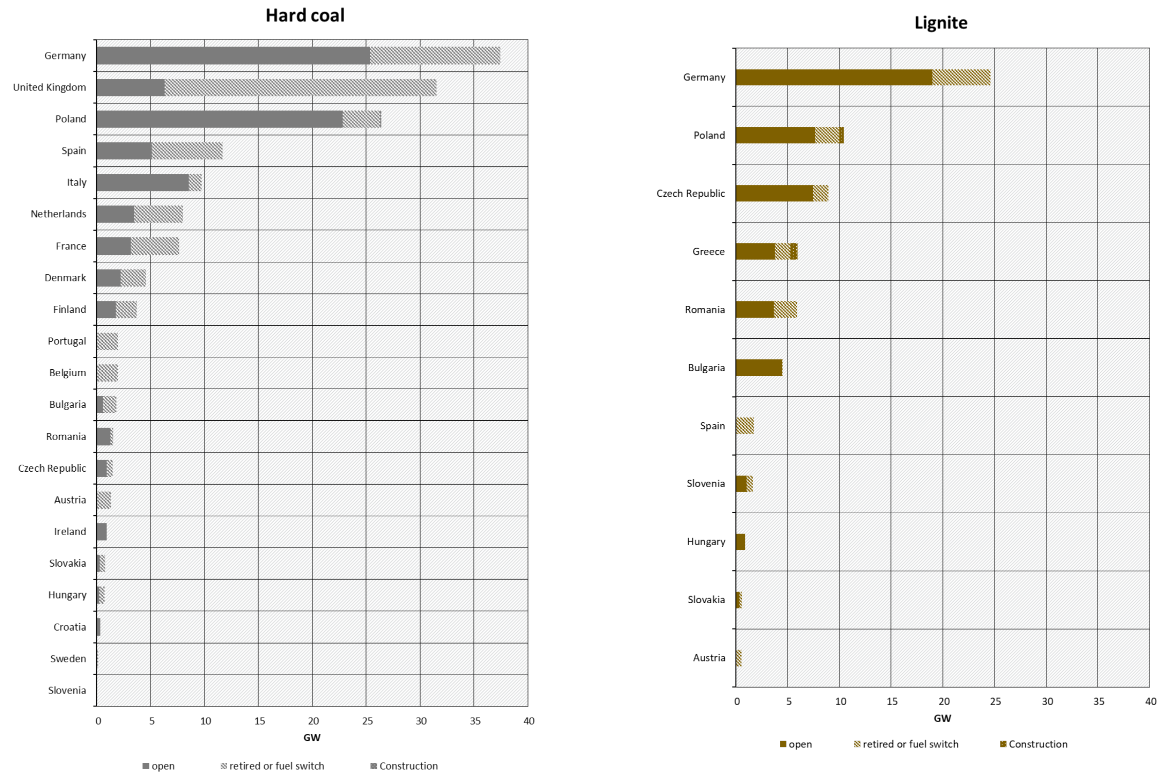
Germany is number one in **hard coal** capacity, followed by the United Kingdom in second place, Poland in third, Spain in fourth and Italy in fifth. These five countries alone account for more than 75 % of the hard coal capacities ever installed in Europe.

The Netherlands and France also have (had) significant hard coal capacities; all other countries shown have (had) less than 5 GW.

Countries that have (or had) **lignite** power plants are fewer in number than those with hard coal capacities as the low energy content of lignite prohibits long transport distances for this fuel. The largest capacities by far are (or were) in Germany. All German lignite capacities (including retired ones) account for 37 % of the lignite capacities shown in this graph. Poland is number two, followed by the Czech Republic as number three, Greece as number four and Romania as number five.

The most retirements of hard coal power plants occurred in the UK (25.2 GW), followed by Germany (12.1 GW) and Spain (6.6 GW). Retirements of lignite power plants could mainly be observed in Germany (5.6 GW), followed by Poland (2.3 GW) and Romania (2.3 GW). Spain retired its last lignite power plant in 2020. There is little hard coal capacity under construction in Poland. Lignite capacity is under construction in Poland and Greece.

Figure 9: EU-28: Coal power plant capacities installed since 1950 by country including retired plants and plants under construction



Source: Own illustration based on data from Europe Beyond Coal (2022).

In the following country fact sheets, we take a closer look at the distribution of capacities between different countries and regions and on the remaining coal and lignite-fired generation fleet.

2.3.2 Future capacity trends

The future of coal in the electricity sector differs between the coal-using European countries; however, most have phase-out plans with different dates (Europe Beyond Coal 2022). There are four countries that have already ceased using coal. These are Belgium (coal phase-out 2016), Austria (2020), Sweden (2020) and Portugal (2021). Hungary and Ireland plan to phase out coal by 2025. Denmark's coal power plants have individual closure dates, the latest being 2028. Finland plans to phase out coal by 2029 according to law. Croatia wants to phase out by 2033 at the latest. In January 2022, Slovenia announced that it would phase out coal by 2033. Slovakia plans to phase out coal by 2030 and Bulgaria announced in October 2021 that it will phase out coal by 2038-2040. At the other end of the scale is Poland, which so far has no official coal phase-out plans at all.

Table 12 shows the coal phase-out dates for the 10 countries examined in more detail in this study. It also includes the 2030 target for renewable energy shares in the electricity generation. Further details on future capacity developments are included in the respective country chapters.

Table 12: Overview of coal phase-out and RES–targets for 10 selected countries

–	Planned coal phase-out in electricity sector	2030 target for RES share in gross generation[1]
Czech Republic	2033 - government announced its intention in January 2022, but plans are not yet determined by law	16.9%
Estonia	2035 - (concerns oil shale, the relevant fossil fuel) according to coalition agreement	40%
France	2027 – President Macron announced in September 2023 that France would extend the life of its two remaining coal plants beyond the originally planned coal phase out –of 2022	40%
Germany	2038 - according to current law; 203–0 - according to coalition agreement	65% - according to –NECP 80% - law has already been passed in 2022 and will come into force in 2023
Italy	2025 - according to a non-binding energy strategy of 2017, confirmed in 2019. Due to delays in the expansion of Sardinia's connection to the mainland, the coal-fired power plant there will continue to operate until 2027.	55%
Netherlands	2029 - operation of last coal power plants must cease at the end of 2029 according to current law	70% - according to NECP 75% - according to latest Climate and Energy Report (KEV) 2021
Poland	No phase-out plans, government announcement to keep coal until 2049	32%
Romania	2030 - according to a law passed in June 2022	49%
Spain	2025 - according to the Spanish NECP	74%
United Kingdom	2024 - according to an announcement by the British government in 2020, originally the phase-out was planned for 2025	50%-75% - according to NECP

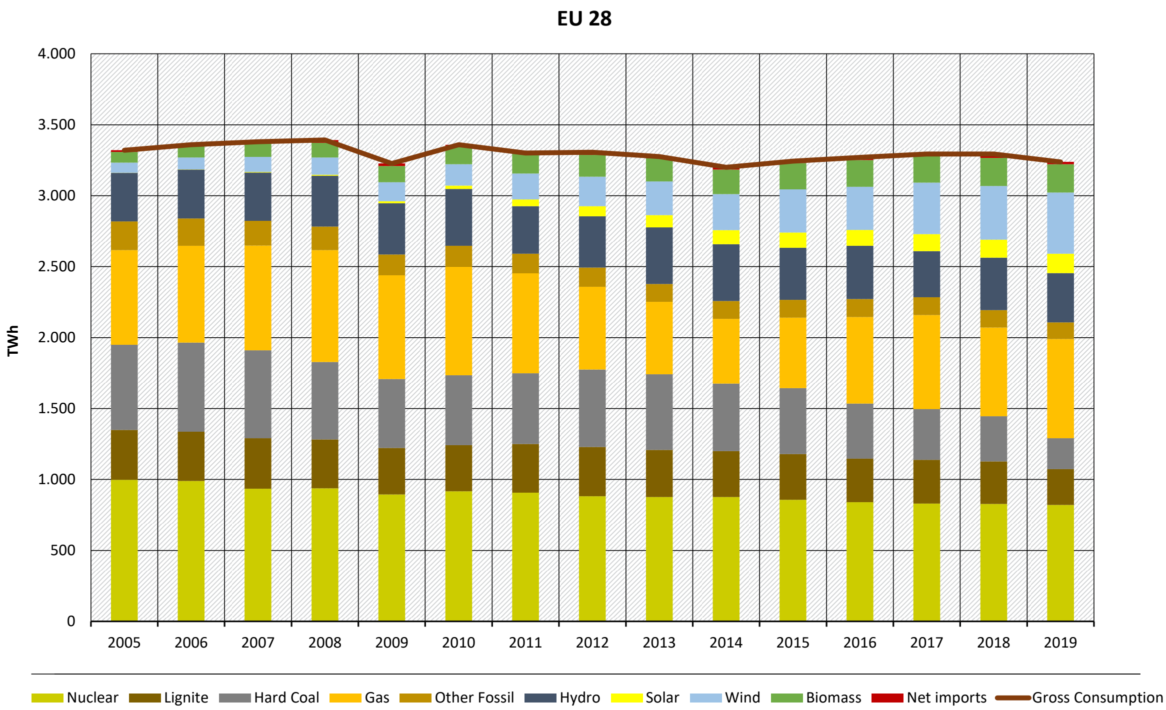
Note: [1] According to Article 4 (2) Regulation (EU) 2018/1999, MSs have to provide information on their contribution to the Union's binding renewable energy target of at least 32 % expressed as renewable energy share on gross final energy consumption. They do so in their NECPs (Article 3(2)(b)). Along with this contribution they also have to report on *estimated trajectories for the sectoral share of renewable energy in final energy consumption from 2021 to 2030 in the electricity, heating and cooling, and transport sector* (see Annex I Regulation (EU) 2018/1999 which sets out the structure of the NECPs)

Source: Own table based on country NECPs,Europe Beyond Coal (2022) and PBL (2021).

2.4 Trends in electricity generation

Figure 10 details the trends in gross electricity production and net imports in the EU-28 from 2005 to 2019. During that period, total gross electricity generation fluctuated between 3200 and 3300 TWh. During the economic and financial crisis in 2009, total production was at levels of 3210 TWh, just 10 TWh below total gross production in 2019. Imports do not play a significant role at the EU-28 level and did not exceed 0.6 % of gross electricity consumption between 2005 and 2019. At the level of the generation mix, there has been a clear shift from coal-fired to renewables-based generation. Coal-fired generation peaked in 2006 with a share of 29 % in total gross electricity production and declined to below 15 % in 2019. The decrease, however, was not gradual but can be divided into four phases: in a first phase, coal-fired generation decreased by 1 % on average between 2007 and 2010. In 2011 and 2012, coal-fired generation saw a brief renaissance, with gross generation increasing again (about 20 TWh per year) and relative shares increasing (about 1.4 % per year). In a third phase from 2013 to 2015, shares again deceased by about 1 % per year. The fourth phase from 2016 to 2019saw a significantly stronger decline of 2.4 % per year.

Figure 10: EU-28: Trends of gross electricity generation and net imports



Source: Ember (2020).

At the same time, the share of renewables-based generation has seen a strong increase from below 5 % in 2005 to about 24 % in 2019. The dynamics can be attributed to generation from biomass, wind and solar. There has not been much capacity extension in hydro generation, the fluctuation of which can be explained by fluctuations in annual precipitation levels. The dynamics have been very different for the three renewable energy sources. Biomass saw a strong increase between 2005 and 2015, with generation increasing by 11 TWh per year on average. From 2016 to 2019 this trend ceased; the annual rise in production is below 4 TWh per year. Both wind and solar generation has seen a strong increase in generation. For wind, two peaks can be identified: one with annual additions of 29 TWh in the years 2011 to 2013 and the current phase in which annual additions amount to 50 TWh and higher. Solar generation saw a similar first peak in the years 2011 to 2013 with average annual additions of 21 TWh. Since, solar generation continued to increase, though at a slower pace of 8 TWh per year on average.

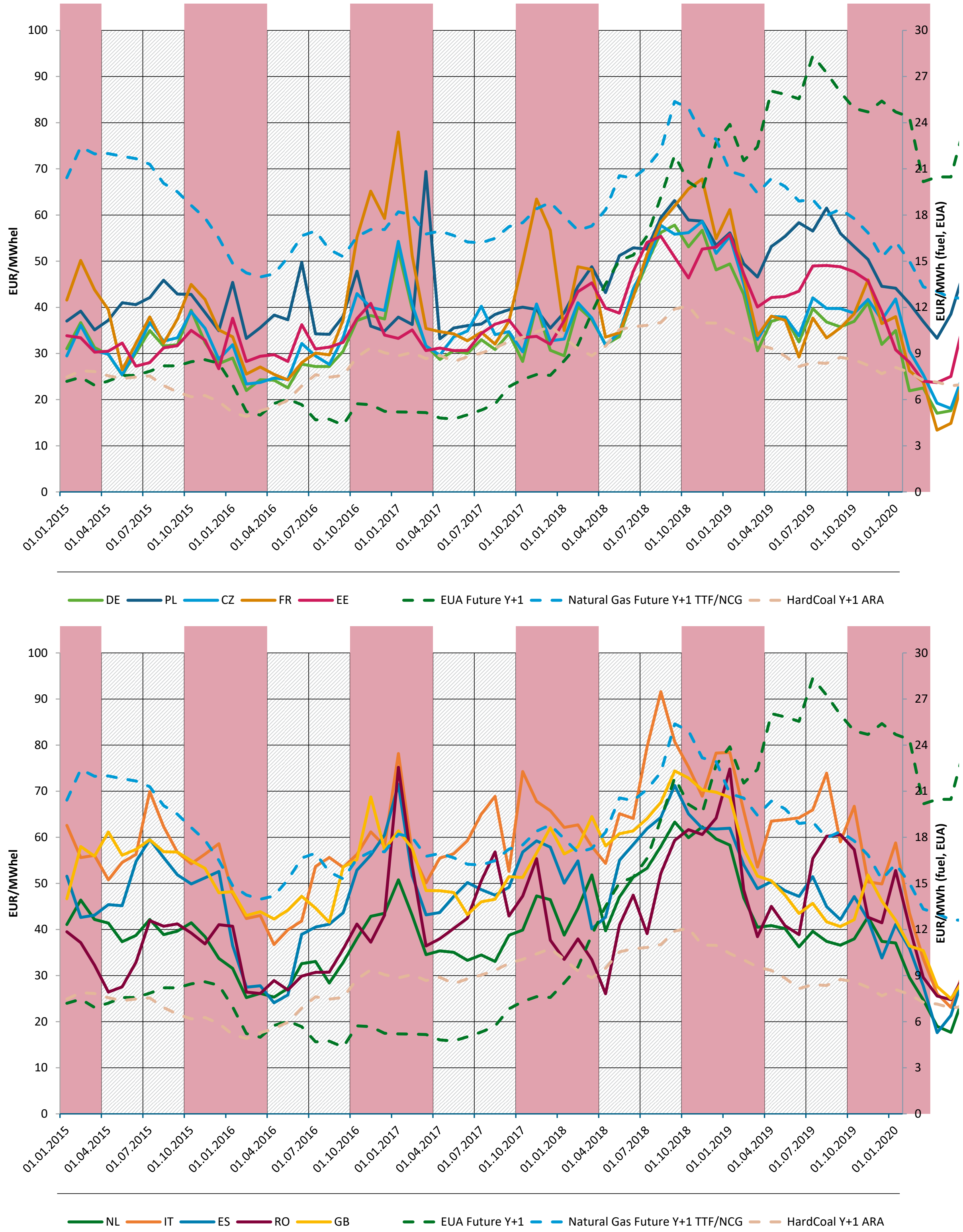
Nuclear generation has seen a steady decline in the share of total gross production, from 30 % in 2005 to 26 % in 2019 (0.3 % per year on average). A kink in the decline can be observed between 2006 and 2007: here the decrease of 55 TWh (1.7 %) originates from reduced generation in France, Germany and the UK.

As a marginal fuel in most electricity systems in the EU-28, gas-fired generation has developed reciprocally to the joint supply from renewables, nuclear and coal. Its share in total gross production can be divided into three phases: between 2005 and 2011, gas-fired generation had a share of around 22 %. In the period from 2012 to 2014, increasing renewable generation and strong competition from coal-fired generation (driven by low CO_2 prices in the EU ETS and high gas prices) reduced the share of gas-fired generation to 14 %. In the phase until 2019, gas-fired generation benefitted from lower gas prices and higher CO_2 prices in the EU ETS, thereby its share returned to levels of 22 %.

2.5 Evolution of wholesale electricity prices, fuel, CO_2 prices

Figure 11 shows the evolution of monthly average wholesale electricity prices for selected countries that report spot prices to ENTSO-E. Wholesale markets are based on marginal cost pricing; hence the electricity price is primarily an indicator of the short-term cost to supply one additional unit of generation (MWh) to be balanced with current demand levels. Generators bid their respective supply costs to the market (short-term marginal costs). To match demand and supply, bids are organized in ascending order (merit order) and the last bid that clears the market sets the price. Fuel prices and prices for emission allowances, which are also shown in Figure 11, are the main price components for short-term additional supply. Importantly, the spot price takes into account both the short-term availability of additional generation units and the current demand level. The general spread in price levels is driven by the respective generation fleet and the availability of spare capacities, but also by the seasonality of demand. Countries with a large thermal power plant fleet such as Germany, Poland and the Czech Republic (nuclear, lignite and hard coal), France (nuclear) or Estonia (oil shale) show comparably lower wholesale prices than countries in which generation is dominated by gas-fired units (such as Italy, the UK or Spain). The figure also highlights the different structure of seasonal demand. Southern countries such as Spain, Italy and Greece have their demand peak in the summer, when electricity is needed for cooling. Northern countries tend to have their demand peak and hence also their electricity price peak in the winter, when electricity is required for lighting and is also broadly used for heating (the latter is true especially in France or the UK). Countries in which a large share of the generation fleet consists of units with high emission intensities (lignite and coal-fired units in Germany, Poland and the Czech Republic, and oil shale in Estonia) react more sensitively to the increase in emission allowance prices, while those countries in which natural gas is the marginal fuel throughout the year are more sensitive to changes in the price for natural gas. Due to low and constant fuel costs and no international trade, lignite-fired unit are not sensitive to international market trends, while hard coal-fired units are, hence hard coal-fired units react sensitively to international market prices and EU ETS CO_2 prices. With an increasing share of renewable generation, weather conditions now play an even more important role as a determinant of wholesale prices than they used to when determining additional electricity demand in cold winters or hot summers. Due to the interconnectedness of the European electricity system, and the various influencing factors, assessing causal effects between single factors and wholesale prices would require substantial further analysis which goes beyond the scope of this report.

Figure 11: Development of fuel prices, price for EU ETS emission allowances and average electricity prices in selected EU countries



Note: The figure shows monthly average values. For countries with several bidding zones values indicate maximum values.
Source: EEX (2023), ICE 2022, ENTSO-E.

Changes in fuel prices or changes in prices for emission allowances can lead to a different dispatch of the generation fleet. An increasing carbon price may shift the dispatch according to the CO_2 intensity of the underlying fuel, i.e. emission-intensive power generation is substituted by low emission-intensive power generation. The fuel switching potential describes the potential for total emission reductions (in t CO_2) related to power generation due to a change of the merit order induced by changes in relative supply costs for the generators. The size of this fuel switch potential depends therefore primarily on the structure of the power plant fleet in a certain region (e.g., the availability of both emission-intensive and idle gas generation plants and the efficiency of these plants), the prevailing type of contracts (e.g. long- or short-term contracts) and the potential for electricity trade with other regions (interconnectors)).

The yearly assessment of the fuel switch potential by the German Environment Agency (Deutsche Emissionshandelsstelle (DEHSt) im Umweltbundesamt 2019; 2020; 2021; DEHSt 2022; 2023) shows that between the end of 2018 and mid-2021 CO_2 prices in combination with relatively low natural gas prices reduced the profitability of hard coal-fired power plants to the extent that it was more economical to generate electricity in natural gas-fired power plants. Lignite power plants benefit from comparably low and stable costs for domestically produced lignite. Nevertheless, in early 2021, high CO_2 prices also led to negative profit margins for lignite power plants. The situation changed drastically in the second half of 2021 as natural gas prices rocketed in relation to an increasingly tightened supply and subsequent to the Russian invasion of Ukraine. Despite high CO_2 prices coal-fired power plants were more economical than natural gas-fired units.

3 Czech Republic

3.1 Key messages

- In 2019, combustion installations (Activity Code 20) in the Czech Republic emitted 49 Mt CO_2, which made the Czech Republic the 7th largest emitter (5 %) in this category. Electricity producers account for 90 % of emissions under this category. Between 2013 and 2019, emissions from electricity generators decreased by only 11 % (which is similar to the Netherlands; electricity-related emissions fell more sharply in all other Member States analysed).

- The generation mix is dominated by lignite-fired generation (41 %). Hard coal has a small share of only 2 %. While the latter declined by 75 % between 2013 and 2019, the former decreased by only 1 %. Over 80 % of the coal-fired generation fleet was installed before 1990. Nuclear is the second pillar of electricity generation contributing about one third of total generation. Gas-fired capacity has increased to 2 GW since 2013 but increased its share in generation only when CO_2 prices went up in 2018 and 2019.

- Electricity supply from renewables has a low share of 13 % in 2019 and has not shown a strong dynamic in recent years.

- The Czech Republic is a net exporter of electricity in the Central European electricity system. Due to its location in the system, it also provides transit capacity for generation from northern Germany to southern Germany in times of high wind generation in the north (loop flows). These loop flows have declined in recent years with increasing demand in Poland and the installation of phase shifters.

- Coal-fired generation is dominated by state-owned ČEZ company (60 % of coal-fired generation in 2019). A coal phase-out by 2038 was recommended by a national coal commission convened by the Czech government in December 2020. In January 2022, the new centre-right government, elected in October 2021, announced its intention to phase out coal by 2033. The plans had not been cast in law by the time this report was completed, however.

Table 13: Czech Republic: Key figures on the electricity sector in 2019

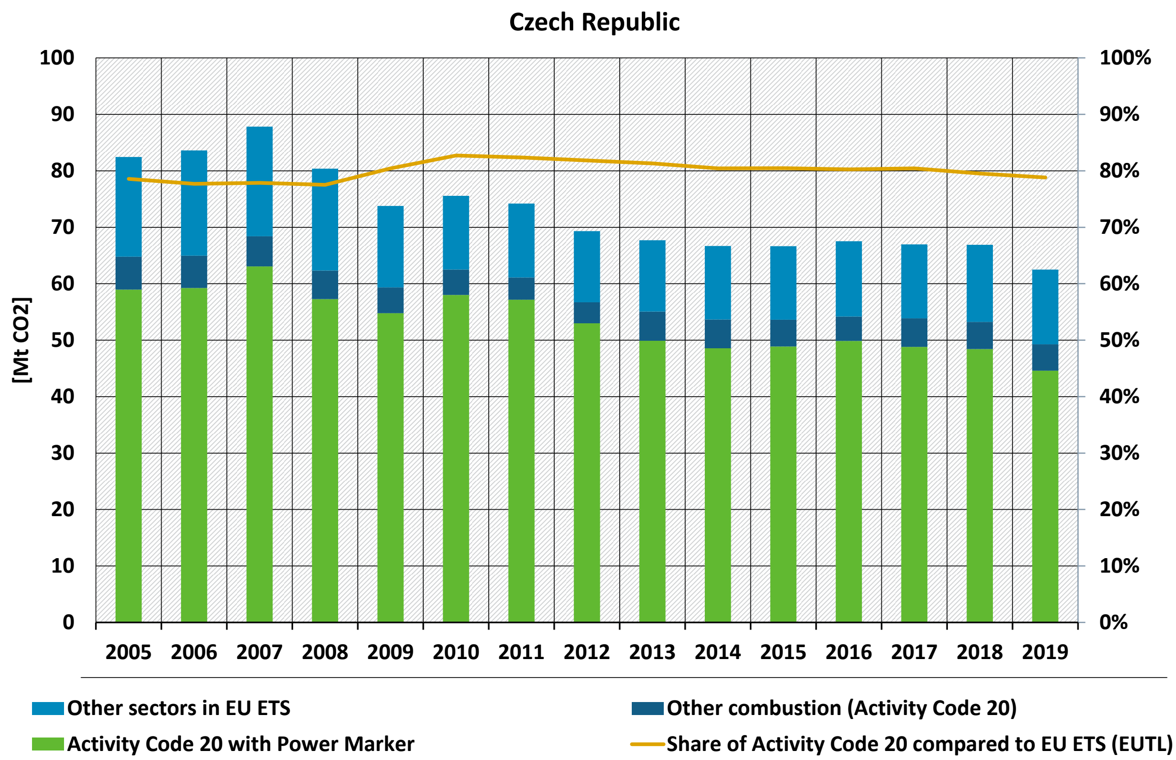
	2019	% change compared to 2013
	CO_2 emissions	
Total CO_2 emissions in 2019 from ETS Activity Code 20 (share of EU-28)	49 Mt CO_2 (5%)	-11%
Total CO_2 emissions from electricity producers[1] (share of Activity Code 20 in the country)	45 Mt CO_2 (90%)	-11%
Emission factor of gross electricity production[2] (relative to EU-28 average)	0.52 t CO_2/MWh (216%)	-10%
	Gross electricity generation	
Total (share of total EU-28)	86 TWh (3%)	0%
Net electricity imports	-13 TWh	-26%
Lignite share in gross generation (share of total gross lignite-fired generation in EU-28)	41% (14%)	-1%
Hard coal share in gross generation (share of total gross hard coal-fired generation in EU-28)	2% (1%)	-75%
RES share in gross generation (target for 2030)[3]	13% (17%)	10%
	Installed capacity	
Total lignite-fired capacity installed (share of total EU-28)	7.8 GW (15%)	-4%
Share of lignite-fired capacity installed before 1990 (share of total EU-28)	81% (13%)	-5%
Total hard coal-fired capacity installed (share of total EU-28)	1.4 GW (1%)	-3%
Share of hard coal-fired capacity installed before 1990 (share of total EU-28)	85% (2%)	-6%

Note: [1] CO_2 emissions from electricity producers based on power plants identified in Oeko-Institut's EU ETS database.
[2] Emission factor calculated based on CO_2 emissions by power plants identified in Oeko-Institut's EU ETS database and gross electricity production reported by Ember (2020).
[3] According to Article 4 (2) Regulation (EU) 2018/1999, MSs have to provide information on their contribution to the Union's binding renewable energy target of at least 32% expressed as renewable energy share on gross final energy consumption. They do so in their NECPs (Article 3(2)(b)). Along with this contribution they also have to report on *estimated trajectories for the sectoral share of renewable energy in final energy consumption from 2021 to 2030 in the electricity, heating and cooling, and transport sector* (see Annex I Regulation (EU) 2018/1999 which sets out the structure of the NECPs)
Source: Own table based on Ember (2020), EC n.d., Europe Beyond Coal (2022), and EEA (2021).

3.2 Emission trends in the EU ETS (combustion installations)

Figure 12 shows CO_2 emissions from the EU ETS in the Czech Republic from 2005 to 2019. CO_2 emissions from Activity Code 20 (combustion installations) accounted for 59 to 63 Mt CO_2 between 2005 and 2007, decreased during the economic crisis in 2008/2009 and remained on a stable level of about 55 Mt in the years 2012 to 2018. In 2019, emissions decreased to less than 50 Mt CO_2 for the first time. The share of Activity Code 20 in the total ETS emissions increased after the economic crisis as industrial emissions decreased disproportionally. The share of combustion installations in emissions was highest between 2010 and 2012, at about 82 %. Since then, it has decreased slightly and amounted to 79 % in 2019.

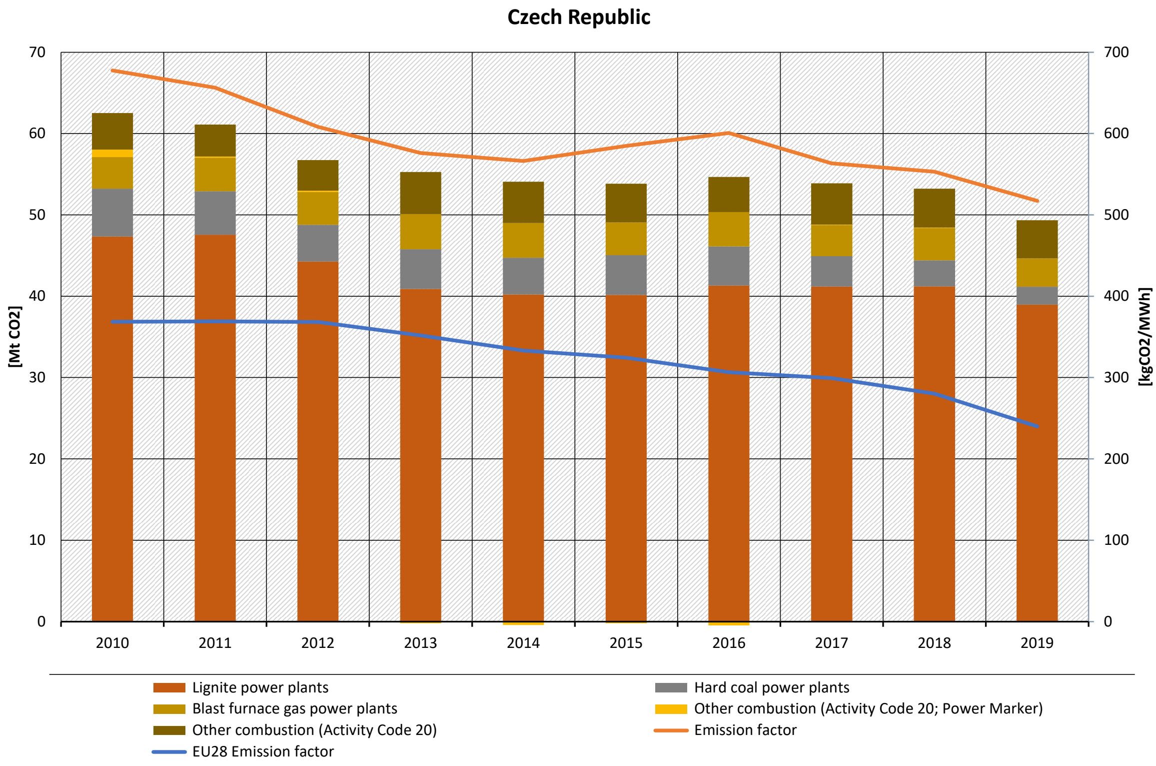
Figure 12: Czech Republic: Emission trends in the EU ETS



Source: Own compilation of data based on EC n.d., and EEA (2021).

Figure 13 shows combustion emissions disaggregated by fuel. CO_2 emissions from lignite power plants amount to about three quarters of the emissions covered. Hard coal and lignite power plants considered together cause 85 % of the total emissions from combustion installations. The remaining share is divided mainly between blast furnace gas and other combustion. A decrease in emissions from lignite-fired generation amounting to 6.5 Mt can be observed between 2011 and 2013. Hard coal emissions decreased from about 5 Mt CO_2 to 2 Mt CO_2 between 2016 and 2019.

Figure 13: Czech Republic: Emission trends from combustion installations in Activity Code 20



Note: "Other Combustion (Activity Code 20, Power Marker)" includes blast furnace gas and natural gas fired power plants. Emissions in the category: other combustion (Activity Code 20; Power Marker) are calculated using the deduction method: All emissions with Power Marker minus emissions from lignite and hard coal-fired power plants.
Source: Own illustration based on data from Europe Beyond Coal (2022), EEA (2021), Ember (2020), and own assignment based on EC n.d..

The emission intensity of gross electricity generation[1] decreased from 680 kg CO_2/MWh in 2010 to 520 kg CO_2/MWh in 2019. It continues to be twice as high as the EU-28 average.

3.3 Capacity trends

3.3.1 Existing capacities

Lignite power plants with a capacity of about 8 GW represent the biggest share of installed capacity. This number has remained almost constant since 2010 as is shown in Figure 14.

In 2016, two of the five 210 MW units at the ČEZ owned Prunéřov II lignite-fired power plant were retired (Blocks 21 and 22). In the same year, the remaining three units were retrofitted in order to extend their lifetime by 25 years (Global Energy Monitor Wiki 2020b). Further retirements of lignite units are under way in 2020 and 2021, which total 1.8 GW. These are blocks at Ledvice II, Melnik II and III and Prunerov I also owned by ČEZ, as well as the Vresova power plant owned by Sokolovská uhelná, which changed fuel from gasified lignite to natural gas in 2020.

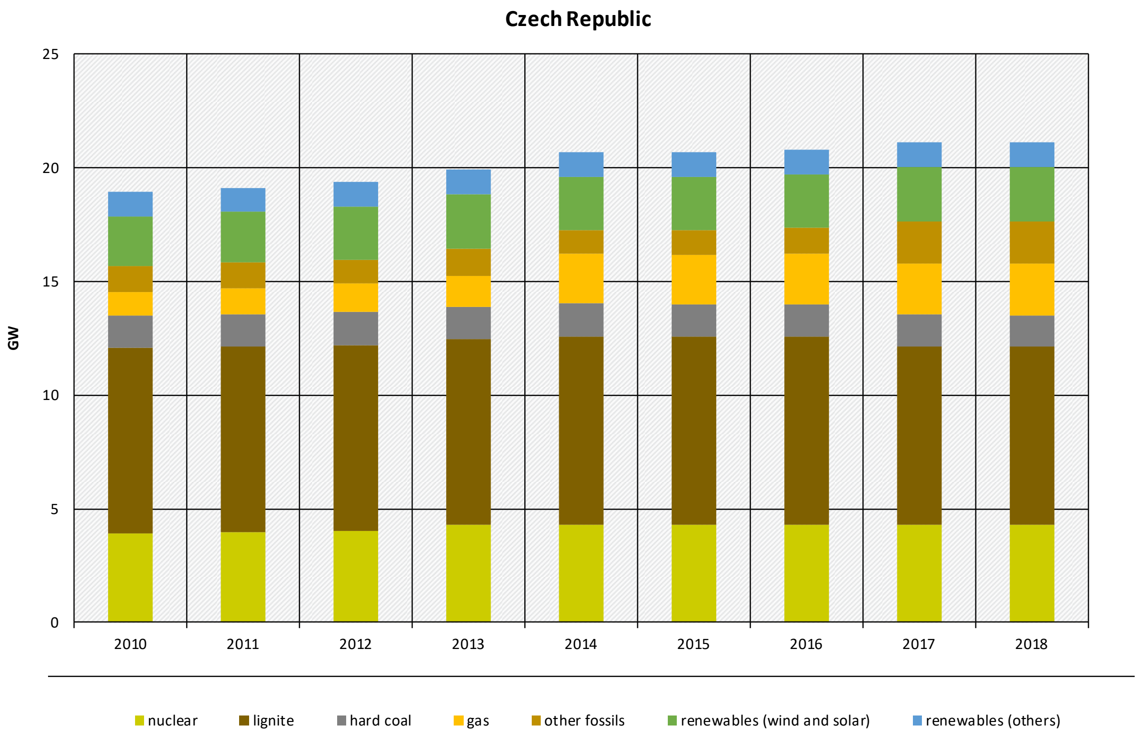
[1] The emission intensity of gross electricity generation is calculated based on CO_2 emissions by power plants identified in Oeko-Institut's EU ETS database and gross electricity production reported by Ember 2020; EEA 2022. It might differ from the values given under European Environment Agency (EEA) 2022.

Hard coal power plants in the Czech Republic had an installed capacity of about 1.4 GW between 2010 and 2018. Capacity decreased in 2019 and 2020 due to the retirement of two blocks in Dětmarovice which had a combined capacity of 400 MW.

Gas-fired power plants total more than 2 GW today. Capacity has increased significantly in 2014. **Solar** capacities grew quickly in the Czech Republic between 2005 and 2010 but have remained on a constant level of about 2 GW since then. Between 2010 and 2018 the installed capacity of **wind** turbines increased from about 200 MW to about 300 MW.

The Czech Republic also operates six **nuclear** reactors at two sites, in Temelín and in Dukovany, which have a combined installed capacity of 4.3 GW (IAEA 2018).

Figure 14: Czech Republic: Evolution of capacity trends by energy carrier



Source: Own illustration based on data from Energy Regulatory Office (2016), Energy Regulatory Office (2019), Europe Beyond Coal (2022).

Figure 15 shows the age structure of coal-fired power plants in the Czech Republic. Capacities that are retired today or have undergone a fuel switch are shown in paler colours. There have been three major phases of investments:

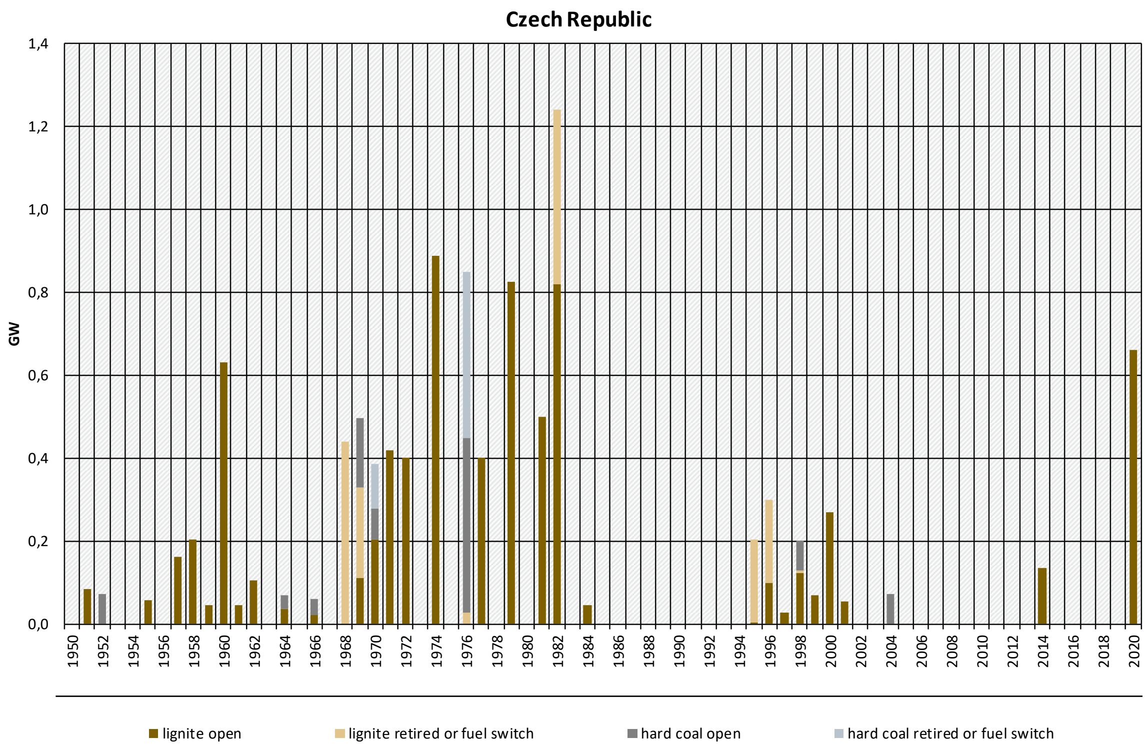
- Between 1950 and the mid-1960s, lignite power plants with a typical capacity of 20 to 60 MW started operating in different lignite mining areas in the country. These plants comprise a combined capacity of about 1 GW and are still operational today.
- Between 1968 and 1984, new lignite power plants came into operation every year or every second year. These had a typical capacity of about 100 MW until 1971 and more than 200 MW from 1971 onward. They amount to 5.3 GW; 3.6 GW of this are still operational. Most investments in hard coal-fired generation units occurred in this period: The largest

hard coal-fired power plant consists of four 200 MW blocks in Dětmarovice, two of which are being retired (see above).

After a period with no further investments in the late 1980s and early 1990s, new coal-fired power plants, mainly lignite-fired, took up electricity production in 1995 and after. Many of these were small units with a capacity of less than 100 MW, but also the two blocks in Vresova, fired by gasified lignite, fall into this period (mid-1990s) as well as two 135 MW blocks in Kladno (commissioned in the year 2000).

The only coal power plants that have started operating since 2005, the starting year of the EU ETS, are another 135 MW block at the Kladno power plant in 2014 and a 660 MW unit at Ledvice in 2020. There are no plans for new coal-fired power plants after the commissioning of this newest lignite unit in 2020.

Figure 15: Czech Republic: Age structure of lignite and hard coal power plants sorted by year of commissioning



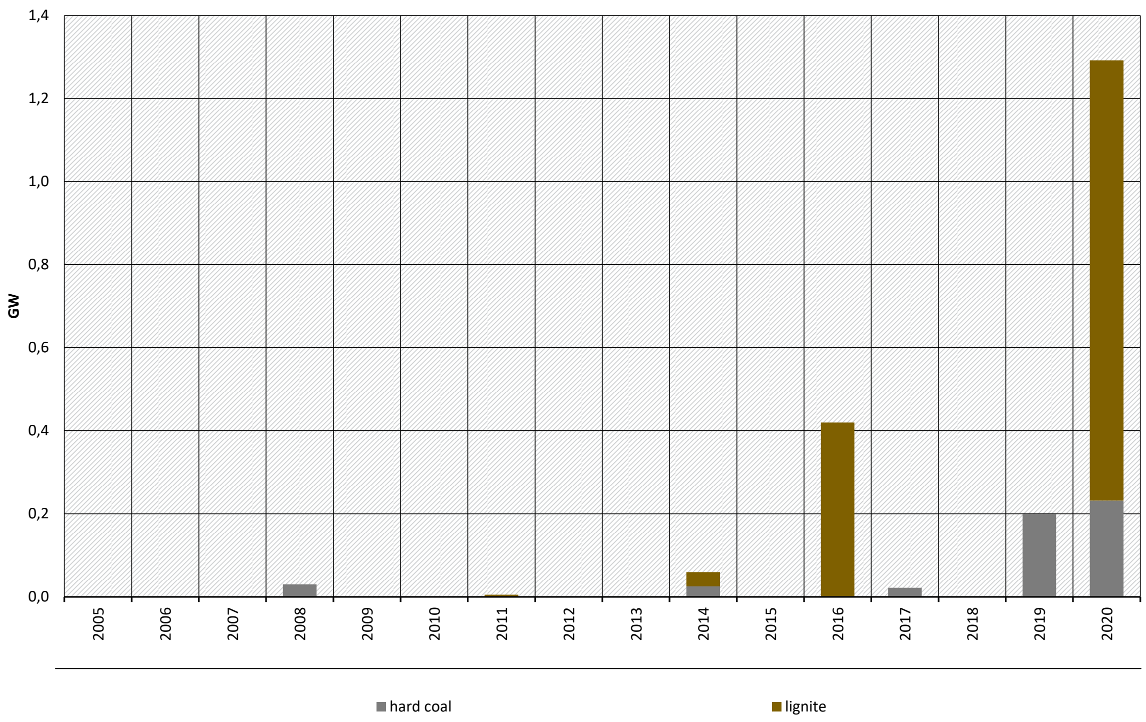
Source: Own illustration based on data from Europe Beyond Coal (2022).

Figure 16 shows the decommissioning of 20 coal-fired power plants in the Czech Republic with a total of 2 GW between 2008 and 2020.

13 lignite units with a total of 1.5 GW were decommissioned (or fuel switched) in 2011, 2014, 2016 and 2020. This included, in addition to three small units of less than 30 MW, six 110 MW units, four of them at the Prunerov power plant and two at the Ledvice power plant, which were decommissioned in 2020, and two 210 MW units at Prunerov, which were decommissioned in 2016. Two 200 MW units at the Vresova power plant were converted to natural gas, as mentioned above.

Seven hard coal units with a total capacity of 0.5 GW were decommissioned in the period considered. Among them are only two 200 MW units (at the Detmarovice power plant, decommissioned in 2019 and 2020); the other five units are small units with a capacity of 30 MW or less.

Figure 16: Czech Republic: Retired coal-fired plant capacities sorted by retirement date



Source: Own illustration based on data from Europe Beyond Coal (2022).

There are two major active lignite mining territories in the Czech Republic, the Ústí region and the Karlovy Vary region, both situated in the north-west of the country. Mines in a third area, the South Moravian region close to the south-eastern border, were shut down in 2014. In the Ústí region, there are four active mines with an annual total production of 33 Mt. Of the two mines in the Karlovy Vary region one was closed after a landslide. The remaining mine delivers about 7 Mt yearly (Koenig et al. 2020).

Due to the relatively high energy density in some Czech lignite, transport to lignite power plants outside the mining areas is also feasible. Hence not all lignite power plants in the Czech Republic are situated in the mining areas, but also close to Prague or more central regions.

The largest hard coal mining area is located near the Polish border. Here the Upper Silesian coal basin, one of the largest in Europe, is divided between Poland and the Czech Republic: five sixths lie in Poland and one sixth in the Czech Republic. In 2018, the output on the Czech side was 4.5 Mt (Euracoal 2020).

3.3.2 Future capacity trends

Conventional power plants

In December 2020, a national coal commission recommended to phase out coal by 2038. The recommendation had not been decided upon due to different positions on the phase-out date within the government coalition. The junior ruling party Social Democrats advocated 2033 as a target date for the coal phase-out and was supported by environmental groups. The Czech government has therefore asked the national coal commission to explore earlier phase-out options than 2038 (Reuters 24 May 2021). In January 2022, the new centre-right government, elected in October 2021, announced its intention to phase out coal by 2033.

Although there is no binding law on the coal phase-out yet, Czech Republic's largest and majority state-owned utility, ČEZ, announced plans in May 2021 to reduce the share of coal-fired electricity generation in their production mix from 39 % in 2019 to 25 % by 2025 and to 12.5 % by 2030 (ČEZ 2021).

The same ČEZ strategy includes nuclear power as a long-term component of the Czech electricity system: lifetimes of existing nuclear power plants are to be increased to 60 years to supply 32 TWh of electricity generation from nuclear power yearly (no target year is given to achieve this level), a new nuclear unit is being planned in Dukovany, and ČEZ wants to look into the construction of small modular reactors (SMRs) to add another 1000 MW after 2040.

Mining areas

Economically recoverable lignite reserves at the active mines in the Czech Republic would last until about 2035 with the current annual output (Euracoal 2020). The physical lignite resources are higher than the reserves by a factor of 3.

Hard coal reserves in the Czech Republic were reported by Euracoal at 23 Mt for 2018. With the current annual output, this would mean that reserves would last until around 2023, while resources on Czech territory are estimated higher than the reserves by a factor of 62.

Future mining activities, especially for lignite mining, are linked with the phase-out date for coal power plants which is still to be decided as described above.

Targets for power generation based on renewable energies

The Czech NECP (Government of Czech Republic 2019; CMS 2020a) foresees a share of renewable energy sources (RES share) in gross final consumption of 16.9 % for the electricity sector by 2030. This would correspond to about 12 TWh, which is barely more than today (see also chapter 3.4). The NECP assumes an installed capacity of just under 7 GW in 2030, of which more than half would be PV.

There has been a support scheme for electricity from renewable sources in the Czech Republic since 2005 (CMS 2020a). However, in August 2013, the Czech Parliament decided to de facto abolish the feed-in tariff scheme for all technologies except small hydro by end of 2013 (RES LEGAL Europe 2019a).

The feed-in tariff is only paid for RES plants that started operation before the end of 2013 (PV and biogas) or the end of 2015 (wind, hydro, geothermal or biomass with building permit issued before 2 October 2013) and an installed capacity of up to 100 kW (30 kW in the case of rooftop or facade PV installations or 10 MW in the case of hydro power plants).

Also the "green bonus," a premium paid on top of the regular market price of electricity, is only available for PV and biogas plants put into operation before 31 December 2013 and for wind, hydro, geothermal or biomass plants with a permit issued before 2 October 2013.

Further support is provided via subsidies for operators of small hydro power plants and PV installations under the Operational Programme "Entrepreneurship and Innovation for Competitiveness" 2014-2020 (OP PIK), which is funded by the European Regional Development Fund (ERDF). Additionally, the Operational Programme "Environment" 2014-2020 (OP ŽP) supports the installation of PV systems by the owners of public buildings via subsidies (RES LEGAL Europe 2019c).

Discussions about a future renewable pathway in the Czech Republic can be expected to continue in the light of the new European target architecture. Only in summer 2021 did the government introduce a new law to promote renewable energies again (Komora OZE 2021). With reference to the new EU climate and RES targets, the Czech electricity company ČEZ announced in May 2021 that it would install renewable plants with a total capacity of 6 GW by 2030 (ČEZ 2021).

3.3.3 Ownership structure of coal power plants

Table 14 shows the list of companies that own coal-fired power plants in the Czech Republic. With 60 % of the total capacity ČEZ is the largest operator of coal-fired power plants. 32 lignite-fired power plants account for the largest share with 4.6 GW in their coal portfolio. ČEZ also owns two hard coal power plant blocks with a total capacity of 0.4 GW.

The second largest coal power plant operator is Severní Energetická with a share of 15 % of the total Czech coal capacities. These are formed by 10 lignite blocks with a total capacity of 1.3 GW. EPH is number three with 17 small lignite blocks and a total capacity of 689 MW. 5 % of the Czech coal capacity is owned by Veolia; their power plants are mainly fired with hard coal. There are ten other companies with smaller market shares operating coal power plants in the Czech Republic as detailed in Table 14.

Table 14: Czech Republic: Ownership structure of the coal-fired electricity generation fleet

	Gross generation capacity by fuel type [MW]		Company's share of total coal capacity	
Owner	lignite	hard coal	share (%)	cumulative share (%)
ČEZ	4641	400	60%	60%
Severní Energetická a.s.	1288	0	15%	75%
EPH	689	0	8%	84%
Veolia	17	367	5%	88%
Sokolovská Uhelná a.s.	289	0	3%	92%
Pražská teplárenská a.s.	0	165	2%	94%
TAMEH Czech	154	0	2%	95%
Plzeňská teplárenská a.s.	137	0	2%	97%
ŠKO-ENERGO s.r.o.	70	0	1%	98%
LAMA ENERGY GROUP	50	0	1%	98%
C-Energy Bohemia spol. s r.o.	46	0	1%	99%
EnergoFuture	42	0	0%	99%
Actherm	26	0	0%	100%
Komterm	0	19	0%	100%

Source: Own table based on Europe Beyond Coal (2022).

3.4 Trends in electricity generation and import balance

Figure 17 shows the gross electricity generation and gross consumption as well as the net exports of electricity in the Czech Republic differentiated by energy carrier since 2005. Consumption is more or less constant on a level of about 70 TWh with a one-year drop due to the economic crisis in 2009. There has been a slightly increasing trend in consumption to about 74 TWh in recent years.

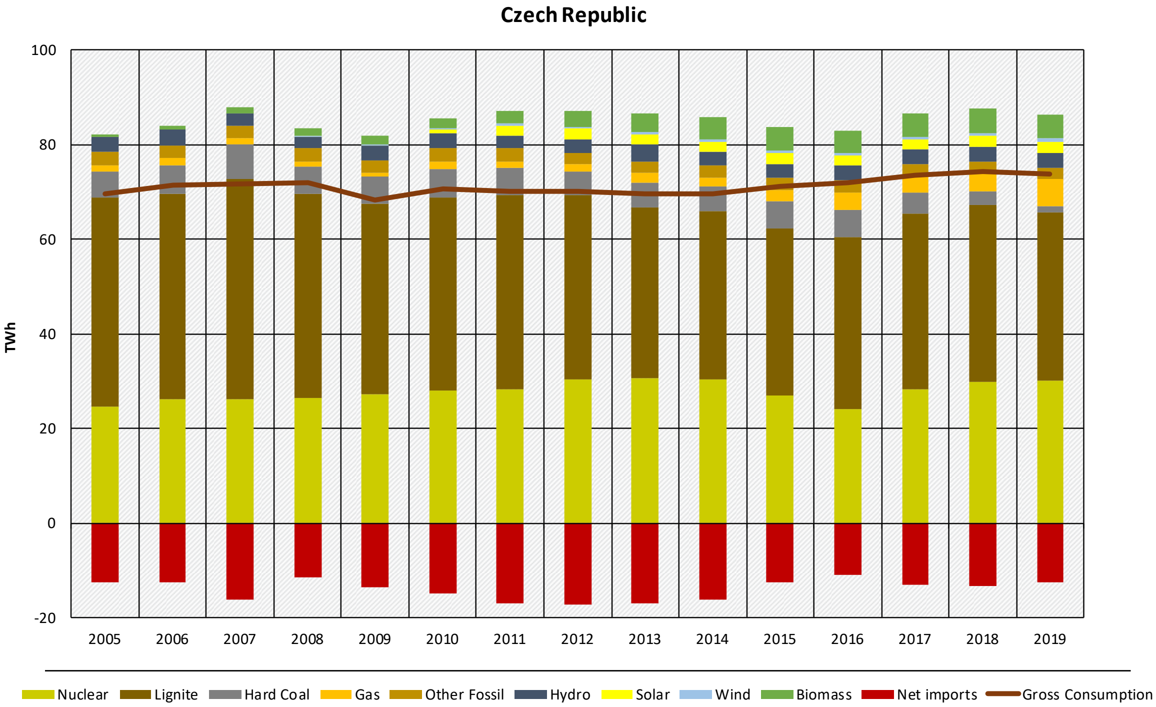
While **lignite** comprised the largest share of generation in 2005 (53 %) with 44 TWh, its generation decreased to 35 TWh and a share of 41 % in 2019. This decline happened in two steps: a first decrease is observed between 2007 and 2009, a second between 2011 and 2013. This correlates with the decrease in CO_2 emissions from lignite for the years 2011 to 2013, as described in chapter 3.2. Interestingly, lignite capacities seem to be constant in this period; thus, the lower electricity generation seems to be caused by either a lower technical availability or market effects.

After lignite, **nuclear** constitutes the second largest share in electricity generation with 25 to 30 TWh in the time period considered, which comprises about one third of the total generation. **Hard coal** contributes much less with 5 to 6 TWh in the years 2005 to 2016 and fell to only 1.3 TWh (2 %) in 2019.

Gas-fired generation plays a minor but increasing role in the Czech generation mix and is the new number three in electricity generation, with almost 6 TWh (7 %) in 2019.

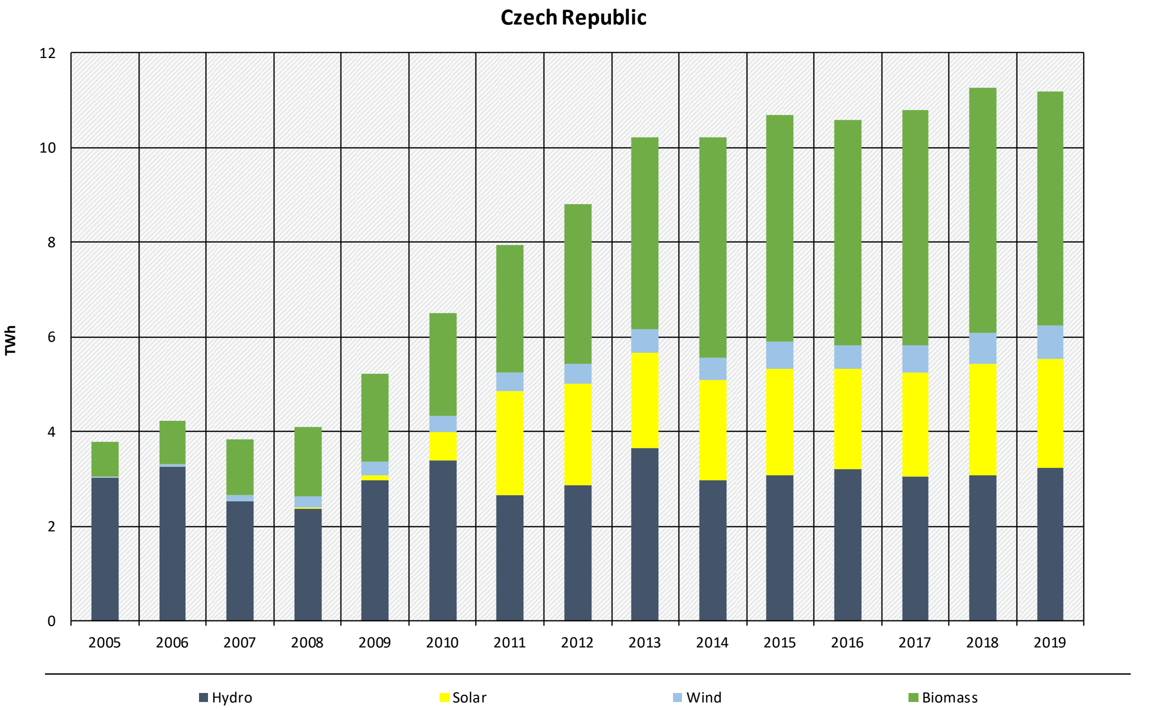
Renewable energies (see Figure 18) have increased from less than 4 TWh to more than 11 TWh. Hydro power plants contribute a constant baseline of about 3 TWh to this amount, with annual fluctuations due to weather effects. Generation from biomass (including biogas) now has the largest share in the renewable mix. Solar electricity generation ramped up with high speed between 2009 and 2011, but has remained on a level of about 2 TWh since then. Wind energy has seen a slow growth with less than 1 TWh to date.

Figure 17: Czech Republic: Trends of gross electricity generation and net imports



Source: Ember (2020).

Figure 18: Czech Republic: Electricity generation of renewable energies

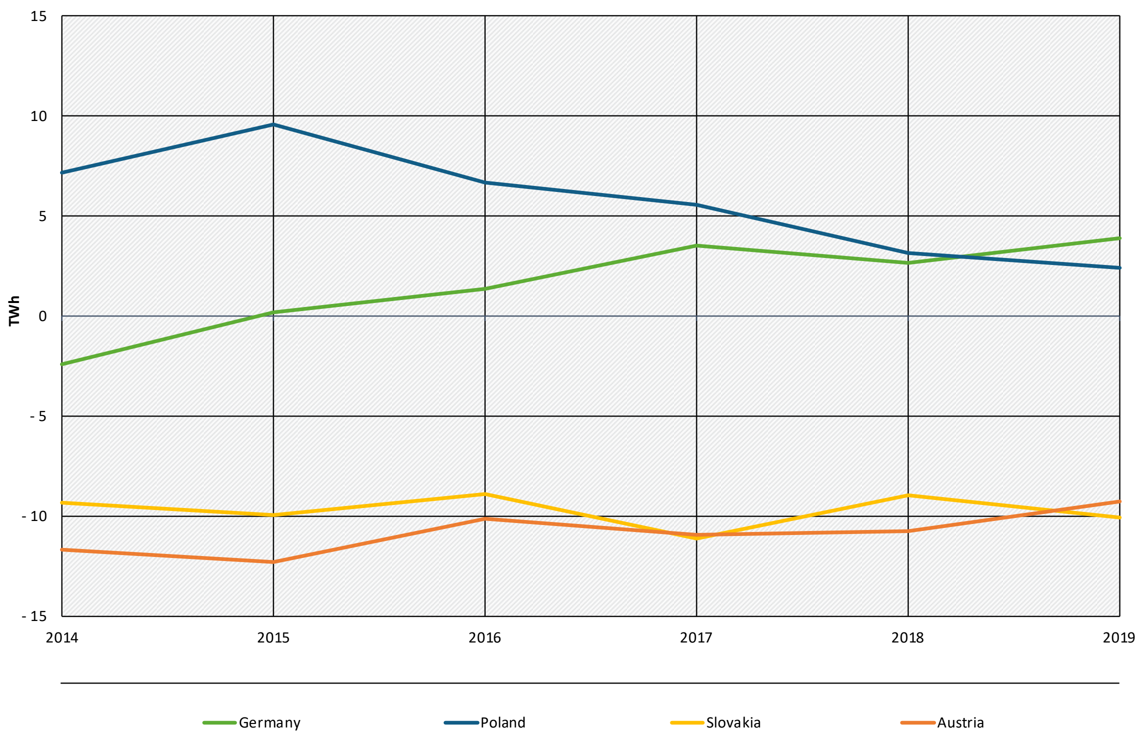


Source: Ember (2020).

The Czech Republic is a net exporter of electricity, as is also shown in Figure 17. Annual net exports vary between 14 and 17 TWh. The Czech Republic is (or was) part of the loop flow pattern of electricity from Northern Germany via Poland and Czech Republic back to Germany, as described in chapter 9.4. As Polish consumption has increased since 2015/16, Polish pass-through of electricity from Germany to the Czech Republic has decreased. As a result, also net exports from Czech Republic to Germany decreased and switched direction to net imports from Germany since 2015. In order to prevent the Czech grid from overflows of electricity from Northern Germany to Southern Germany and Austria, phase-shifting transformers were installed at the Czech-German transmission line that connects the ČEPS grid with the German 50 Hertz zone. Phase-shifting transformers were commissioned first on the Czech side at the Hradec sub-station in January 2017 and later, in January 2018, on the German side at the Röhrsdorf sub-station (ČEPS; 50 Hertz 17 Jan 2018).

Figure 19 shows net electricity exchange between the Czech Republic and its neighbours for 2014 to 2019. While flows to and from Germany and Poland changed during this period as described above, comparably high net exports both to Slovakia and to Austria took place on an almost constant level of about 10 TWh.

Figure 19: Czech Republic: Net import (positive) and net export (negative) of electricity, physical exchange with neighbouring countries



Source: Energy Regulatory Office (2016), Energy Regulatory Office (2019).

3.5 Market setting

3.5.1 Regional market allocation and interconnectors

The Nominated Electricity Market Operator (NEMO) in the Czech Republic is called "OTE, a.s.". OTE offers a day-ahead market, an intraday market and a block market for certain fixed time blocks for electricity. A second trading platform is Power Exchange Central Europe (PXE). PXE also trades on the electricity futures market and offers power trading of standardised products for the Czech, Slovak, and Hungarian markets (CMS 2015).

Together with ČEPS, a.s., the national transmission system operator OTE also works on the market integration of the Czech electricity market: The Czech Republic is part of the 4M Market Coupling (4M MC), which includes the Czech Republic, Hungary, Romania and Slovakia. It is planned that this electricity market will connect with the Europe-wide Multi Regional Coupling (MRC) in order to introduce single day-ahead coupling in a total of 23 European countries. The next step to achieving this goal is the so-called Interim Coupling project, which will facilitate Single Day-Ahead coupling and the geographical extension to all relevant EU borders. After some delay, the Interim Coupling project went online in June 2021 (TSCNET Services 2020; Serbia Energy 2015; OTE 2021; BiznesAlert 2019).

Table 15 shows the net transfer capacity of the Czech interconnectors according to ENTSO-E with the largest transfer capacities to Germany and Slovakia.

Table 15: Czech Republic: Net transfer capacity with neighbouring countries in 2018 (MW)

		DE[1]	AT	PL	SK
CZ	To	1442	670	600	1766
CZ	From	1235	620	817	1200

Note: [1] For Germany, the values are based on BNetzA; BKartA (2022).

Source: Own data based on ENTSO-E.

3.5.2 Electricity market design with reference to conventional power generation plants

There is no capacity market in the Czech Republic.

Article 10 c of the EU ETS Directive allows some Member States to use free allocation for investments in the modernization and diversification of the power sector. In the Czech Republic, this free allocation covered 54 % of emissions from power plants in 2013 and decreased to 9 % in 2019. For the fourth period of the ETS, the Czech Republic decided to use the possibility of transferring all its Article 10c volumes to the Modernisation Fund, thereby increasing its volume and share of spending under the Fund (EC).

CHP has a long tradition in the Czech Republic. In March 2021, the Czech government reported under the Energy Efficiency Directive (EED) about their plans to transform district heating and CHP by 2030 (Ministerstvo průmyslu a obchodu 2021). According to this presentation, a new system of operational support shall be introduced, which focuses not only on the new sources of heat, but also on the modernization of current sources. This includes a new support scheme for CHP production based on competitive auctioning and feed-in premiums support for small CHPs.

In addition, new schemes of investment subsidies for CHP plants are planned: For example, it is planned that the recovery and resilience fund will provide support for the modernization of heat distribution networks (such as steam to water switching). The EU ETS modernization has a program is specially devoted to the transition of district heating producers from coal to low carbon sources.

4 Estonia

4.1 Key messages

- In 2019, combustion installations (Activity Code 20) in Estonia emitted 6 Mt CO_2, which made Estonia the 22nd largest emitter (1 %) in this category. Electricity producers account for 96% of emissions under this category. Between 2013 and 2019, emissions from electricity generators decreased by 57 %.
- The generation mix is dominated by oil shale-fired generation, which accounted for more than 85 % of total production between 2005 and 2018. With an increasing CO_2 price, the share has dropped below 80 % in 2019.
- Estonia is increasingly integrated with neighbouring countries. The country's position in the Nord Pool electricity market is highly reactive to CO_2 price signals. With increasing CO_2 prices, the country has changed from a net exporter of electricity, exporting 20 % or more of its generation in the years before 2019, to a net importer, supplying almost 30 % of consumption by imports in 2019.
- Due to the pivotal role of oil shale in electricity generation, the average emission factor of gross electricity generation is about 1.0 Mt CO_2 per MWh, which is more than four times higher than the EU-28 average emission factor in 2019.
- Energy supply from renewable sources plays an increasing role and comprised 22 % of total gross generation in 2019, an increase of about 140 % compared to 2013.
- The new coalition plans to cease power generation from oil shale by 2035, and to achieve a 40 % RES share in electricity generation by 2030. It plans to do so mainly by expanding wind generation but has also installed a working group to assess the prospects of introducing nuclear power generation in Estonia.

Table 16 Estonia: Key figures on the electricity sector in 2019

	2019	% change compared to 2013
	CO_2 emissions	
Total CO_2 emissions in 2019 from ETS Activity Code 20 (share of EU-28)	6 Mt CO_2 (1%)	-56%
Total CO_2 emissions from electricity producers[1] (share of combustion installations in the country)	6 Mt CO_2 (96%)	-57%
Emission factor of gross electricity production[2] (relative to EU-28 average)	0.99 t CO_2/MWh (414%)	-5%
	Gross electricity generation	
Total (share of total EU-28)	6 TWh (0%)	-55%
Net electricity imports	2 TWh	-162%
Lignite share in gross generation (share of total gross lignite-fired generation in EU-28)	0% (0%)	0%
Hard coal share in gross generation (share of total gross hard coal-fired generation in EU-28)	0% (0%)	0%
RES share in gross generation (target for 2030)[3]	22% (40%)	138%
	Installed capacity	
Total lignite-fired capacity installed (share of total EU-28)	0	
Share of lignite-fired capacity installed before 1990 (share of total EU-28)	0	
Total hard coal-fired capacity installed (share of total EU-28)	0	
Share of hard coal-fired capacity installed before 1990 (share of total EU-28)	0	

Note: [1] CO_2 emissions from electricity producers based on power plants identified in Oeko-Institut's EU ETS database.

[2] Emission factor calculated based on CO_2 emissions by power plants identified in Oeko-Institut's EU ETS database and gross electricity production reported by Ember (2020).

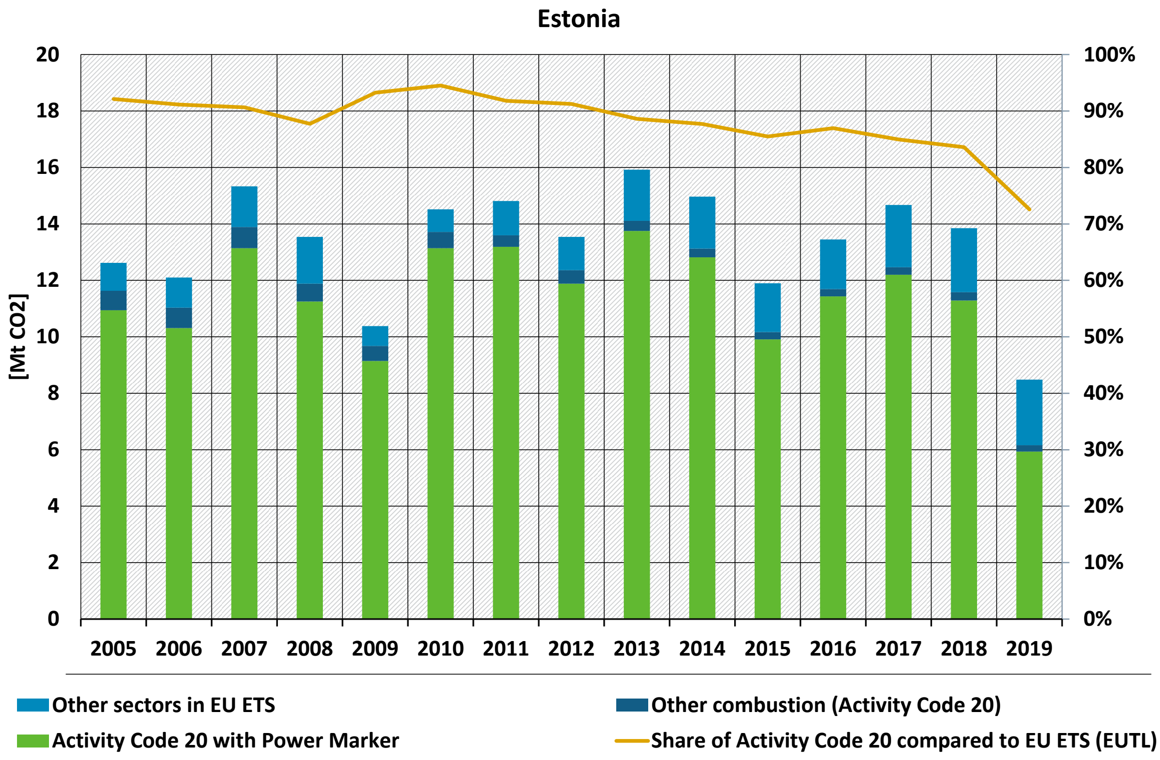
[3] According to Article 4 (2) Regulation (EU) 2018/1999, MSs have to provide information on their contribution to the Union's binding renewable energy target of at least 32% expressed as renewable energy share on gross final energy consumption. They do so in their NECPs (Article 3(2)(b)). Along with this contribution they also have to report on *estimated trajectories for the sectoral share of renewable energy in final energy consumption from 2021 to 2030 in the electricity, heating and cooling, and transport sector* (see Annex I Regulation (EU) 2018/1999 which sets out the structure of the NECPs)

Source: Own table based on Ember (2020), EC n.d., Europe Beyond Coal (2022), and EEA (2021).

4.2 Emission trends in the EU ETS (combustion installations)

Figure 20 shows CO_2 emissions from the EU ETS in Estonia from 2005 to 2019. CO_2 emissions from Activity Code 20 (combustion installations) were volatile in the period considered. Generally, they fluctuated between levels of 10 and 14 Mt CO_2. A sharp decrease to only 6 Mt CO_2 is to be observed in 2019.

Figure 20: Estonia: Emission trends in the EU ETS



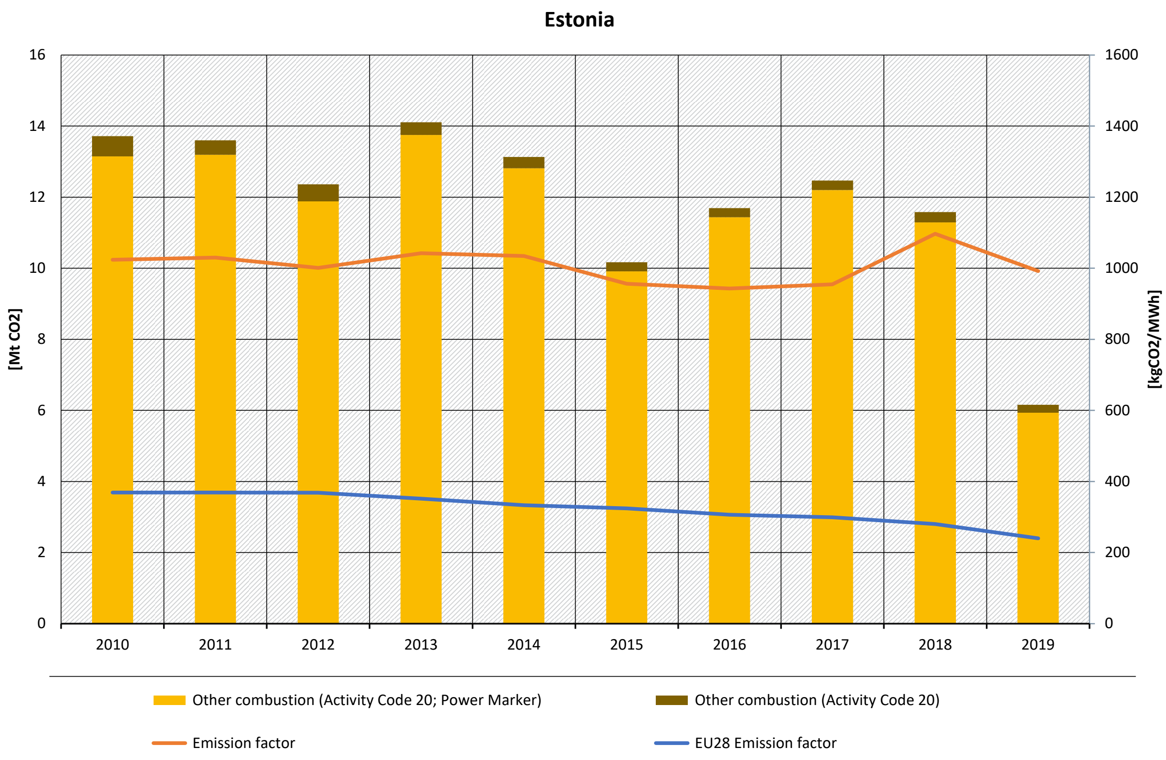
Source: Own compilation of data based on EC n.d., and EEA (2021).

There are no lignite, hard coal or blast furnace gas power plants in Estonia. Therefore, Figure 21 shows emissions disaggregated by the previously mentioned fuels and other combustion emissions for the other fact sheets in this report; it is an excerpt of the preceding figure which shows the combustion emissions only along with the emission factors of Estonia and the EU. Estonia's most important fuel in the power sector is oil shale, a type of sedimentary rock that is rich in kerogen. Together with small amounts of natural gas, emissions from oil shale combustion make up the bars labelled "Other Combustion (Activity Code 20, Öko-Institut Power Marker[2])" in Figure 21.

The emission intensity of gross electricity generation in Estonia ranges around 1000 kg CO_2/MWh due to the high amount of emission-intensive oil shale. It is 2.5 to 4 times (2019) higher than the EU-28 average.

[2] The installations that take part in the EU ETS are published in the EUTL registry without detailed technical information. Oeko-Institut has carried out its own research to identify electricity-generating plants; these are labelled with a marker called "Power" in Oeko-Institut's internal database.

Figure 21: Estonia: Emission trends in Activity Code 20



Source: EEA (2021), Ember (2020), and own calculations based on EC n.d..

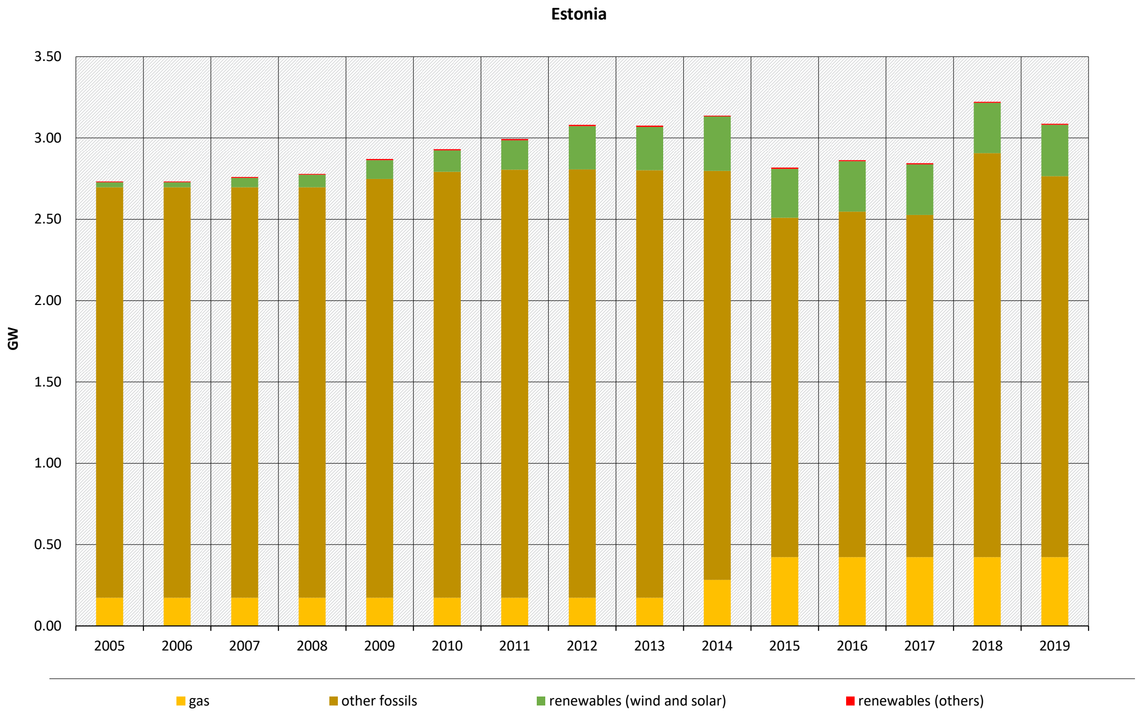
4.3 Capacity trends

4.3.1 Existing capacities

Estonia is the only country that uses oil shale as the dominant fuel in the power sector. Figure 22 shows the capacity of the Estonian power plant fleet by fuel. Eesti Statistika, the Estonian office for statistics, provides data on thermal power plants which is not disaggregated by fuel. The capacity of oil shale power plants was therefore calculated by subtracting the data on gas-fired power plants by ENTSO-E for Estonia. The power plants labelled oil shale in the graph may also use peat or waste and biomass for co-firing. The capacity of oil shale power plants ranges between 2.1 GW and 2.6 GW. The most important power plant location is the Narva power plant complex near the city of Narva close to the Russian border. It consists of the world's two largest oil shale-fired thermal power plants: the Eesti power plant (capacity varies according to different sources between 1369 MW (ENTSO-E 2019) and 1615 MW (Majandus- ja Kommunikatsiooniministeerium 2007)) and Balti power plant (capacity between 472 MW (ENTSO-E 2019) and 765 MW (Majandus- ja Kommunikatsiooniministeerium 2007)). There is another 300 MW block (Auvere power plant, ENTSO-E 2019) close to the Eesti power station.

Natural gas power plants increased their capacity from only 170 MW up to 2013 to more than 400 MW since 2015 with the construction of a reserve power plant in 2013/14.

Figure 22: Estonia: Evolution of capacity trends by energy carrier



Source: Own calculations based on Eesti Statisika 2005-2019, ENTSO-E 2019.

The Estonian office for statistics records an increase in the capacity of wind turbines from 30 MW in 2005 to 270 MW in 2012. Since 2015, the capacity has stagnated at around 300 MW. No data is provided on solar power plants.

Hydropower plants are reported with capacities between 5 and 8 MW in the period under review.

4.3.2 Future capacity trends

Conventional power plants

The gas-fired Kiisa reserve power plant (Wärtsilä 2018) (250 MW) and the oil shale-based Auvere power plant (300 MW) are the newest additions to the conventional Estonian power plant fleet. Both started operation in 2014. The oil shale-based Auvere power plant was reconstructed in 2020/21 to burn waste gas (the source does not further specify the type of waste gases used here) and wood waste and to reduce oil shale to about 15 % of the fuel (Err.ee 2021b). The Estonian coalition formed in early 2021 also plans to stop power generation from oil shale by 2035 at the latest and to stop using oil shale in the entire energy sector by 2040 at the latest (Err.ee 2021a). The Russian invasion of Ukraine, however, has made domestic oil shale more attractive again (Reuters 2022a).

In April 2021, the Estonian government decided to form a nuclear energy working group under the leadership of the Ministry of the Environment to study the possibility of introducing nuclear energy in Estonia. The working group plans to submit its conclusions and proposals to the government by September 2022 (World nuclear news 2021b).

Mining areas

There are two oil shale deposits in north-eastern Estonia. Mining takes place in the "Estonian deposit" between Rakvere and Narva. The reserves are stated in the Estonian Oil Shale Industry Yearbook 2019 by Eesti Energia, Viru Keemia Grupp, Oil Shale Competence Centre at the Talttech Virumaa College 2021 as about one billion tonnes of oil shale that could be extracted "without restrictions" from the total reserves of 4.8 billion tonnes.

However, there is a legal annual extraction limit of 20 million tonnes.

In 2020 (Talttech Virumaa College Oil Shale Competence Centre, Eesti Energia, Viru Keemia Grupp, Kivioli Keemiatööstus 2022), oil shale was mined by three companies: Eesti Energia, Viru Keemia Grupp and Kiviõli Keemiatööstus. A fourth company, Kunda Nordic Tsement, mined oil shale until 2019, but then stopped oil shale mining along with clinker production. In total, 9.2 million tonnes of oil shale were extracted in 2020, which is 3 million tonnes less than in 2019 and less than half of the permitted 20 million tonnes per year.

The Estonian Oil Shale Industry Yearbook 2019 (Eesti Energia, Viru Keemia Grupp, Oil Shale Competence Centre at the Talttech Virumaa College 2021) quoted above also stated: “The high price level of the CO_2 quota inhibited the competitiveness of electricity produced from oil shale in 2019, but according to the decision of the Government of the Republic of Estonia as the owner of Eesti Energia, electricity production capability from oil shale must be maintained, ensuring the production of electricity at the level of the Estonian average consumption - 1,000 MW - until 2023.” The report of the following year, the Estonian Oil Shale Industry Yearbook 2020 (Talttech Virumaa College Oil Shale Competence Centre, Eesti Energia, Viru Keemia Grupp, Kivioli Keemiatööstus 2022) also found an effect of the CO_2 price on the decreasing volume of oil shale mined by Eesti Energia, describing that “they could produce electricity from oil shale only at those times, when the price of electricity on the market became high.”

Targets for power generation based on renewable energies

According to the NECP, Estonia aims to achieve a 40 % share of electricity from renewable sources in 2030. This is to be achieved by building onshore and offshore wind power plants with a total capacity of 1200 MW in 2030 (producing 2.6 TWh) and by increasing solar capacity to 415 MW (producing 0.4 TWh). Hydropower can continue with 8 MW (0.03 TWh), as today. Biomass is projected to deliver 1.2 TWh and to be used also as an additional fuel in oil shale power plants. Together with other renewables, the NECP indicates a total of 4.3 TWh from renewable electricity sources in 2030 (Estonia 2023).

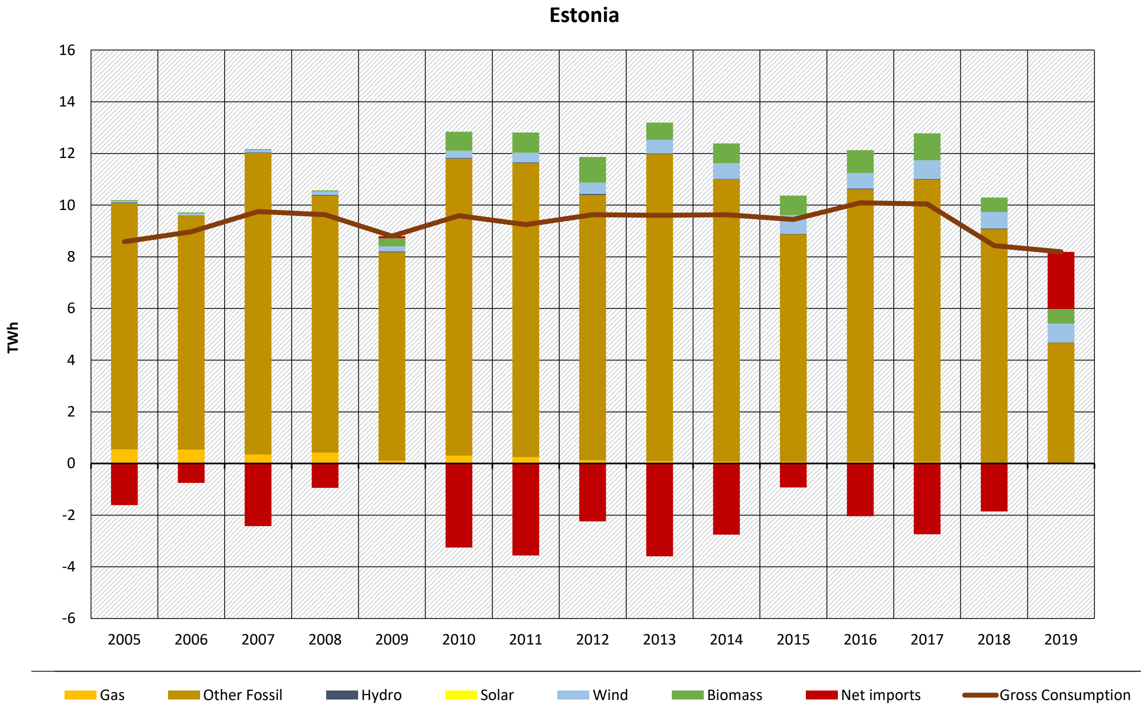
4.3.3 Ownership structure of oil shale power plants

The Eesti power plant, Balti power plant and Auvere power plant all belong to the state-owned company Eesti Energia (Eesti Energia 2022).

4.4 Trends in electricity generation and import balance

Gross electricity consumption fluctuated between about 9 and 10 TWh between 2005 and 2017, reaching a minimum of 8 TWh in 2019. Figure 23 shows the gross consumption as well as gross electricity generation including imports and exports to Estonia between 2005 and 2019, broken down by fuel. Oil shale (here shown within “other fossil”) is the major energy carrier in the Estonian electricity system. It provided between 8 and 10 TWh of electricity in the period 2005 to 2018. In 2019, electricity from oil shale power plants decreased sharply. According to CAN Europe, this is due to increased emission allowance prices in the EU ETS in 2019 and the promotion of green energy (CAN Europe 2020).

Figure 23: Estonia: Trends of gross electricity generation and net imports



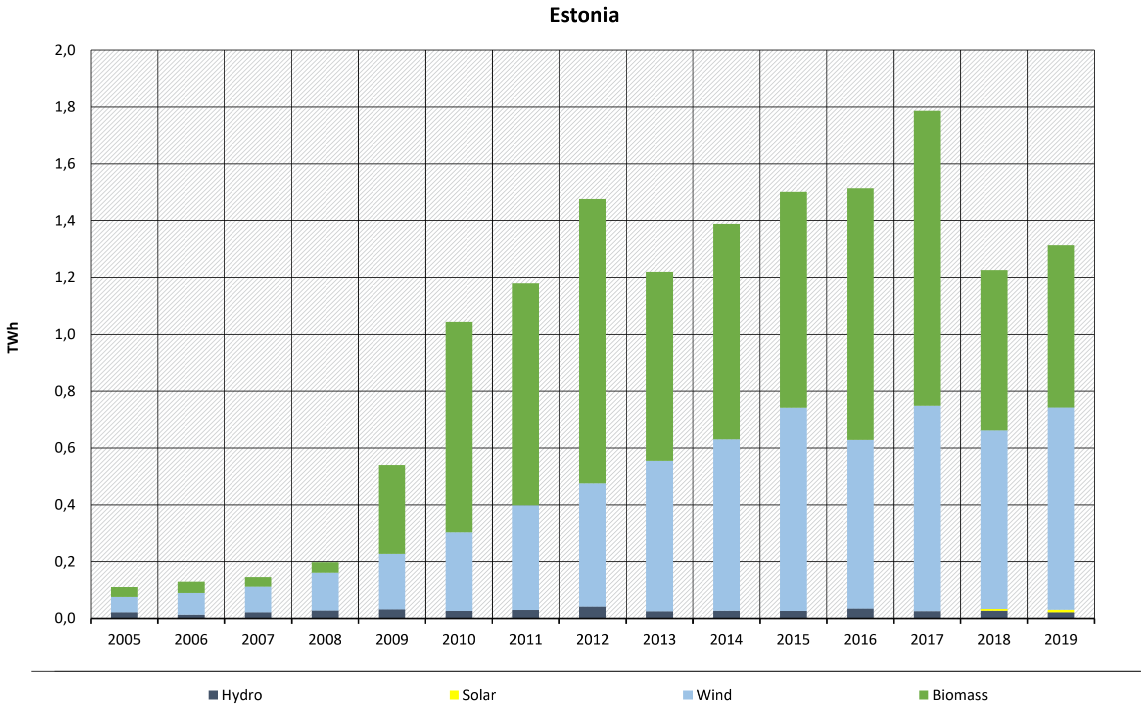
Source: Ember (2020).

As a result, the import-export balance changed from net exports to net imports in 2019.

Electricity generation from natural gas is low, it contributed 0.5 TWh in 2005 and 2006, but since 2013 it has fallen to below 0.1 TWh.

Renewable electricity generation in Estonia is dominated by wind and biomass, as can be seen in Figure 24. Electricity generation from wind energy increased from about 0.05 TWh in 2005 to a level around 0.7 TWh in the years 2015 to 2019. The contribution from biomass was only 0.04 TWh up to 2008 but increased to levels of around 0.8 TWh in the years 2010 to 2019. Hydropower plants generated about 0.03 TWh annually over the entire period. Solar energy has only recently come on the scene and contributed 0.01 TWh in 2019.

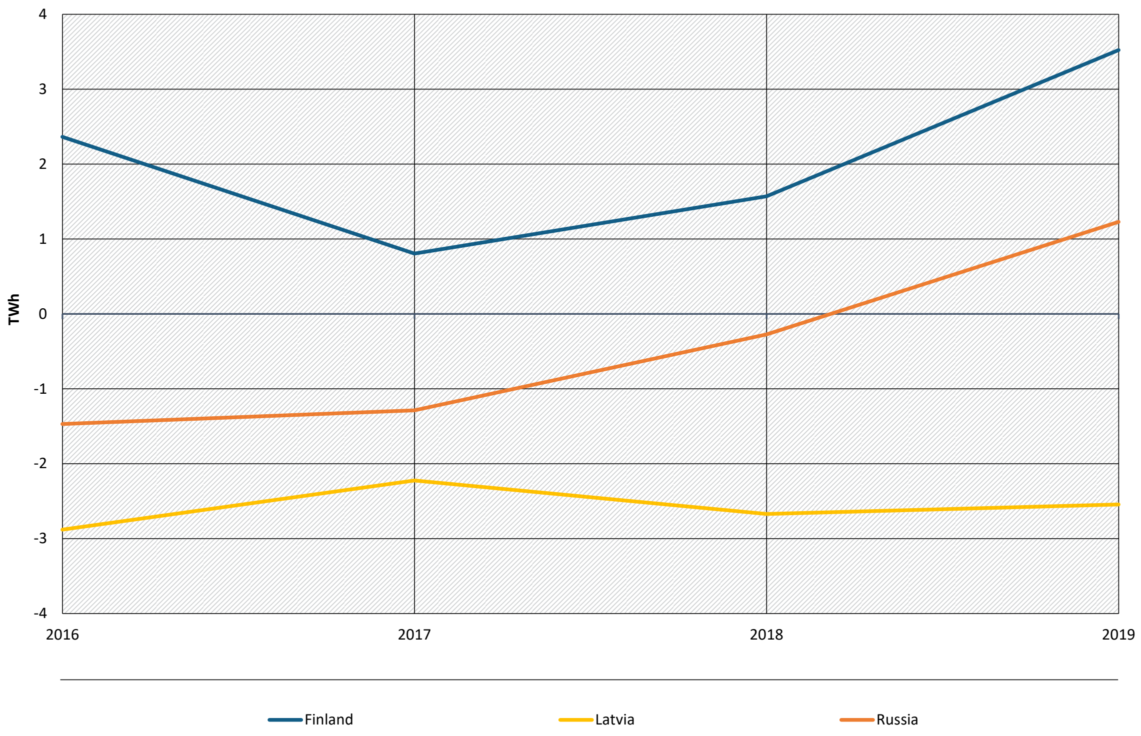
Figure 24: Estonia: Electricity generation of renewable energies



Source: Ember (2020)

Figure 23 also shows the net imports and exports of electricity to and from Estonia. Only in 2009 and 2019 did Estonia import more electricity than it exported. Neighbouring countries connected to Estonia are Finland, Latvia and Russia. Figure 25 shows the yearly net import and net export of Estonia detailed by country between 2016 and 2019. While Estonia had net imports from Finland and net exports to Latvia in all four years, it exported electricity to Russia until 2018 but had net imports from Russia in 2019. Net imports from Finland also increased in 2019.

Figure 25: Estonia: Net import (positive) and net export (negative) of electricity, physical exchange with neighbouring countries



Source: ENTSO-E 2016-2019

4.5 Market setting

4.5.1 Regional market allocation and interconnectors

The designated NEMO (Nominated Electricity Market Operator) in Estonia is Nord Pool EMCO AS. Nord Pool expanded to Estonia in 2010 with a spot market in April and an Intraday market in October 2010 (Nord Pool 2010). The full opening of the Estonian electricity market for all consumers took place on 1 January 2013 (Elering). EPEX Spot SE has also offered services in Estonia since 2019 (Epex Spot 2018).

Estonia is part of the Price Coupling of Regions (PCR) project, an initiative of European Power Exchanges, among them Nord Pool and EPEX Spot, to develop a single price coupling solution. It is currently being used to couple 25 countries (Epex Spot).

Estonia is connected to Finland, Latvia and Russia in this context. There are three 330 kV lines to Russia, and two lines of the same capacity to Latvia. Since 2006 there has been a connection between Finland and Estonia via a 350 MW direct current line, EstLink 1. Since 2014 the additional EstLink 2 cable has increased the total transport capacity to and from Finland to 1000 MW (Republic of Estonia, Ministry of Economic Affairs and Communications) (see also Table 17; data for interconnector to Russia is not available).

Table 17: Estonia: Maximum forecasted transfer capacity with neighbouring countries in 2021 (MW)

		FI	LV	RU
EE	to	1016	1297	n.a.
EE	from	1016	1000	n.a.

Source: Own data based on ENTSO-E.

4.5.2 Electricity market design with reference to conventional power generation plants

The Estonian electricity market is an energy-only market. There is no capacity market.

The Estonian NECP states that one of the largest future changes will be the phase-out of the old oil shale power plants. In 2021, the coalition agreement of the new Estonian government set two phase-out dates: oil shale electricity is to be phased out by 2035 and oil shale production by 2040 at the latest (Err.ee 2021a).

5 France

5.1 Key messages

- In 2019, combustion installations (Activity Code 20) in France emitted 43 Mt CO_2, which made France the 8th largest emitter (5 %) in this category. Electricity producers account for only 41 % of emissions under this category. This is much lower than in the other Member States analysed, for which the share of electricity is around 75 % or higher (another exception is UK). Between 2013 and 2019, emissions from electricity generators decreased by 43 %.
- Coal-fired generation decreased in two waves: one in 2013 to 2015, when a combination of air pollution regulations and the start of auctioning of EU ETS allowances for electricity generation instead of free allocation made the continued operation of these power plants financially less attractive; and one in 2018 and 2019 when higher CO_2 prices induced a fuel switch from coal to gas.
- France is a major exporter of electricity in the Central European electricity system, with 50 TWh of exports on average between 2005 and 2019. Electricity is exported in particular to the United Kingdom and Italy. To a smaller extent, electricity is also exported to Germany and Spain.
- A coal phase-out is planned for 2027, later than originally envisaged. The nuclear fleet will require substantial re-investments in the years ahead; 30 % of the installations are older than 40 years and 88 % are at least 30 years old or more.
- In 2017, France introduced a capacity market in which suppliers are obliged to hold sufficient capacity guarantee certificates which can be traded. Due to the threshold level of 200g CO_2/MWh, gas-fired generation is excluded, and capacity provision comes mostly from nuclear and hydro power plants.

Table 18 France: Key figures on the electricity sector in 2019

	2019	% change compared to 2013
	CO_2 emissions	
Total CO_2 emissions in 2019 from ETS Activity Code 20 (share of EU-28)	43 Mt CO_2 (5%)	-26%
Total CO_2 emissions from electricity producers[1] (share of combustion installations in the country)	17 Mt CO_2 (41%)	-43%
Emission factor of gross electricity production[2] (relative to EU-28 average)	0.03 t CO_2/MWh (13%)	-42%
	Gross electricity generation	
Total (share of total EU-28)	570 TWh (18%)	-2%
Net electricity imports	-61 TWh	26%
Lignite share in gross generation (share of total gross lignite-fired generation in EU-28)	0% (0%)	0%
Hard coal share in gross generation (share of total gross hard coal-fired generation in EU-28)	1% (2%)	-83%
RES share in gross generation (target for 2030)[3]	21% (40%)	15%
	Installed capacity	
Total lignite-fired capacity installed (share of total EU-28)	0 GW (0%)	0%
Share of lignite-fired capacity installed before 1990 (share of total EU-28)	0%	0%
Total hard coal-fired capacity installed (share of total EU-28)	3.2 GW (3%)	-56%
Share of hard coal-fired capacity installed before 1990 (share of total EU-28)	100% (6%)	0%

Note: [1] CO_2 emissions from electricity producers based on power plants identified in Oeko-Institut's EU ETS database.
[2] Emission factor calculated based on CO_2 emissions by power plants identified in Oeko-Institut's EU ETS database and gross electricity production reported by Ember (2020).
[3] According to Article 4 (2) Regulation (EU) 2018/1999, MSs have to provide information on their contribution to the Union's binding renewable energy target of at least 32% expressed as renewable energy share on gross final energy consumption. They do so in their NECPs (Article 3(2)(b)). Along with this contribution they also have to report on *estimated trajectories for the sectoral share of renewable energy in final energy consumption from 2021 to 2030 in the electricity, heating and cooling, and transport sector* (see Annex I Regulation (EU) 2018/1999 which sets out the structure of the NECPs)
Source: Own table based on Ember (2020), EC n.d., Europe Beyond Coal (2022), and EEA (2021).

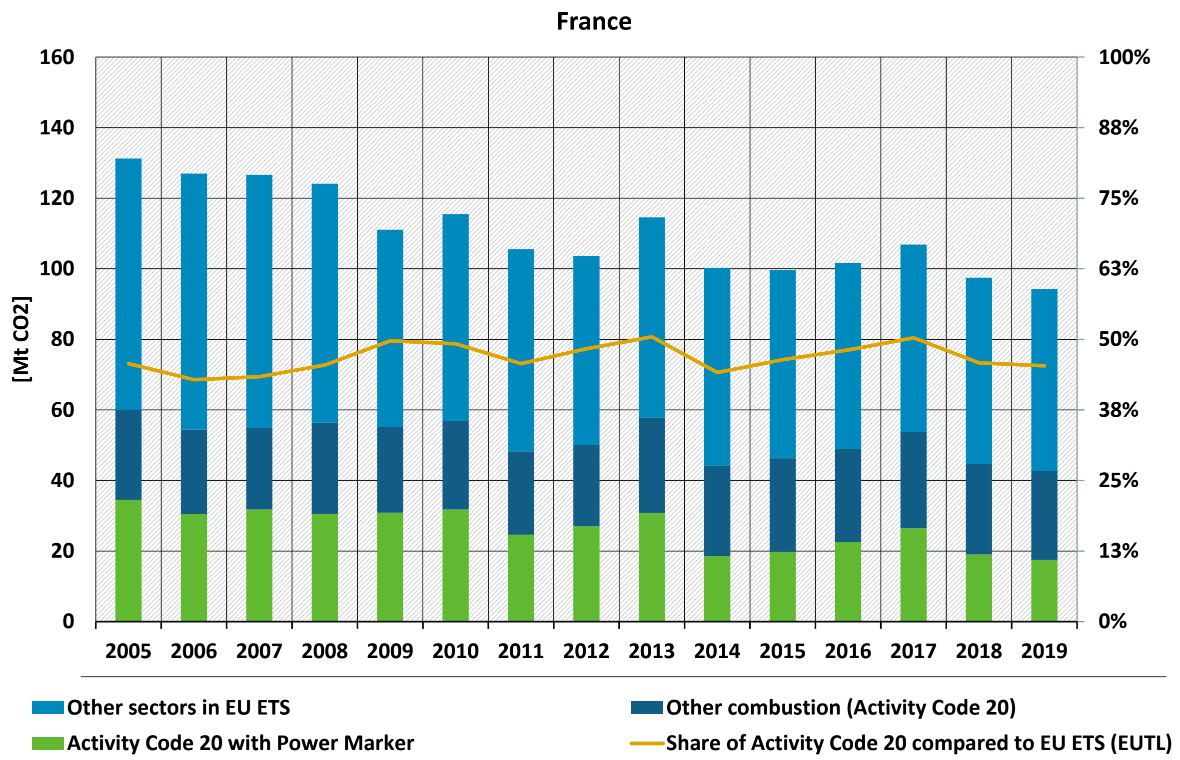
5.2 Emission trends in the EU ETS (combustion installations)

Figure 26 shows CO_2 emissions from the EU ETS in France from 2005 to 2019. CO_2 emissions from Activity Code 20 in the EUTL (combustions installations) constitute a share between 40 % and 50 % of these emissions. Overall, EU ETS emissions dropped from more than 125 Mt CO_2 in 2005 to about 110 Mt CO_2 in 2009. In the period 2010 to 2013, emissions fluctuated between 105 and 115 Mt CO_2, stabilized between 2014 and 2016 at about 100 Mt CO_2 and after a one-year increase to 107 Mt CO_2 in 2017 decreased to 94 Mt CO_2 in 2019.

Emissions from Activity Code 20 and from other EU ETS sectors decreased more or less proportionally compared to the overall EU ETS emissions in France.

As also shown in Figure 26 the electricity sector (Activity Code 20 with Oeko-Institut's Power Marker) has comprised only less than half of emissions under Activity Code 20 since 2014. Other activities included under "combustion" are industrial installations which cannot be attributed to a specific industrial activity listed in the Annex of the EU ETS Directive such as some chemical and food industries as well as heat generation for various industrial purposes.

Figure 26: France: Emission trends in the EU ETS

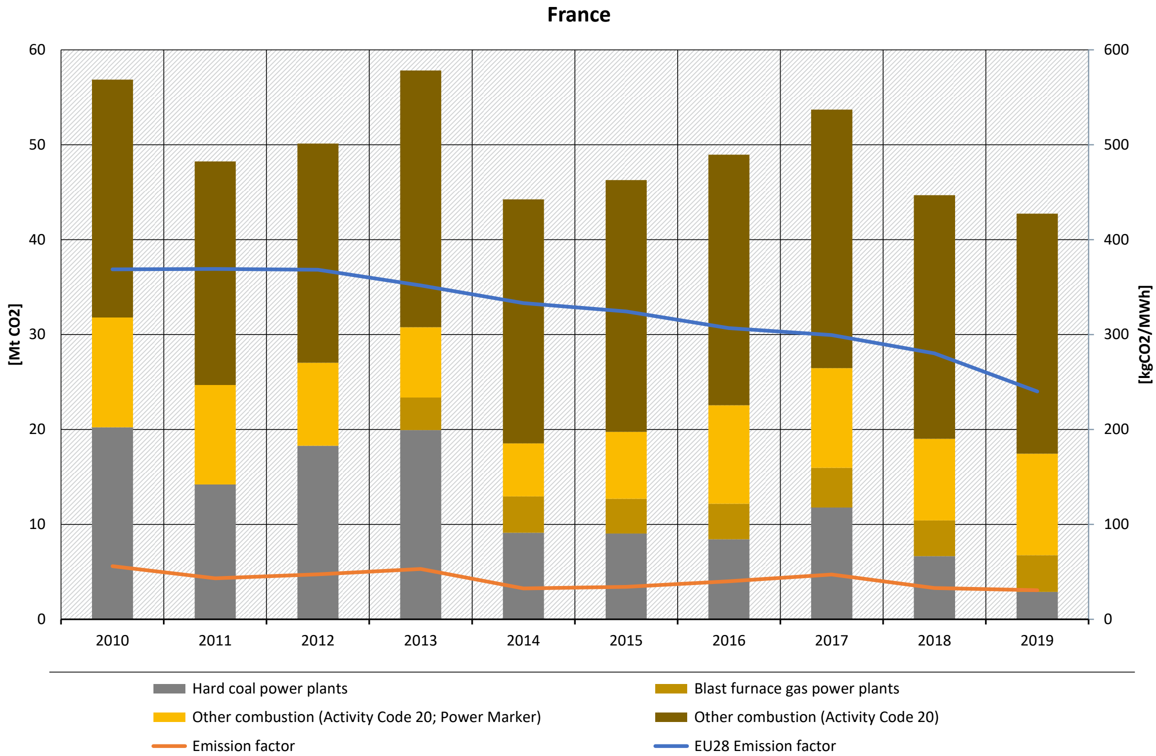


Source: Own compilation of data based on EC n.d., and EEA (2021).

Figure 27 shows CO_2 emissions from Activity Code 20 disaggregated by fuels from 2010 onwards. The emissions from hard coal power plants were reduced from 20 Mt in 2010 to only 3 Mt in 2019. The first major decrease occurred from 2013 to 2014 when CO_2 emissions from hard coal power plants more than halved. The emissions from blast furnace gas power plants increased in France from about 1 Mt in the years 2010 to 2012 to a level of about 5 Mt in recent years. However, this is not due to an increase in steel production but rather a change in the reporting of emissions from blast furnace gas (until 2012, these emissions were reported at the blast furnace, i.e. in the steel industry). All other fossil fuel-based power plants emitted between 6 Mt and 10 Mt in the period under consideration.

The largest single share in Figure 27 comes from other combustion processes that do not generate electricity. In the years shown, they emitted between 23 Mt and 27 Mt. Nearly 40 % of these emissions can be attributed to facilities in the chemical industry which cannot be attributed to a specific industrial activity listed in the Annex of the EU ETS Directive and 20 % to food industries, especially the production of sugar. Furthermore, heat generation for various industrial purposes and for public use is included in this category (about 30 %).[3]

Figure 27: France: Emission trends in Activity Code 20



Note: Emissions in the category: other combustion (Activity Code 20; Power Marker) are calculated using the deduction method: All emissions with Power Marker minus emissions from hard coal-fired power plants minus emissions from blast furnace gas power plants.
Source: Own illustration based on data from Europe Beyond Coal (2022), EEA (2021), Ember (2020), and own assignment based on EC n.d..

The emission factor of France's electricity generation is much lower than the EU-28 average. It decreased from 56 kg CO_2/MWh in 2010 to 31 kg CO_2/MWh in 2019. The low factor is due to the high shares of nuclear and considerable shares of hydro in power generation and a further decrease in coal-fired generation, as shown in Figure 27 and described in more detail below.

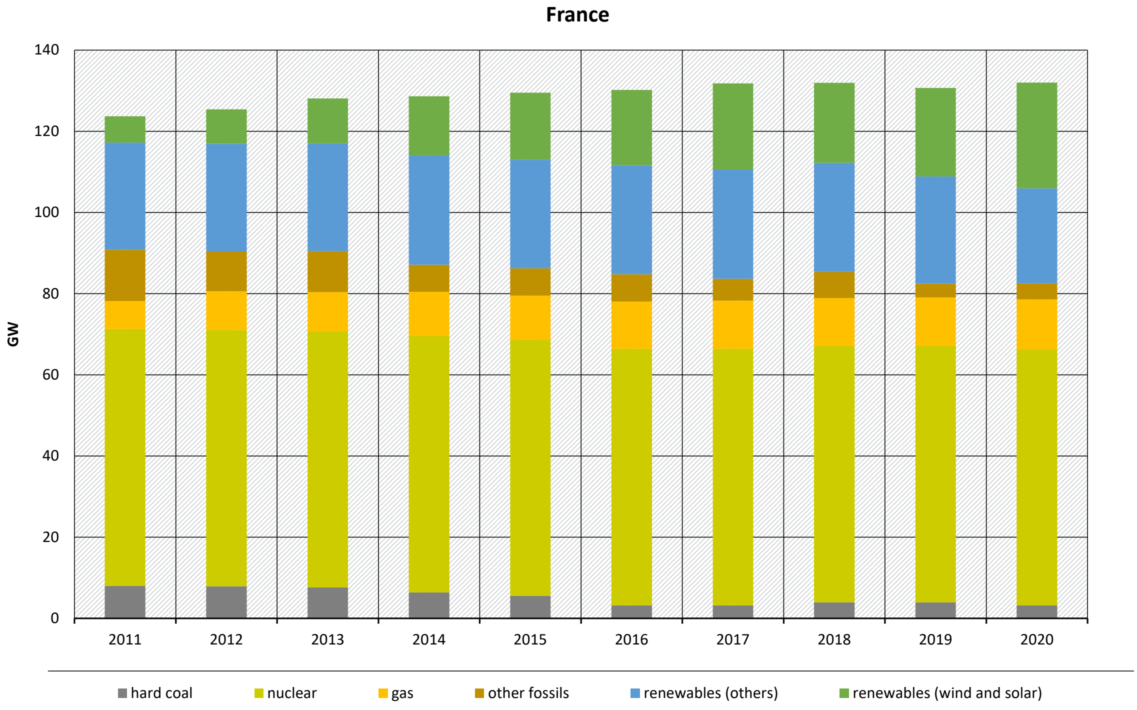
5.3 Capacity trends

5.3.1 Existing capacities

Figure 28 shows the development of the installed capacity of French power plants from 2011 to 2020.

[3] Shares are based on the attribution of ETS installations to NACE codes, forming the basis of the carbon leakage list and refer to emissions in the year 2019.

Figure 28: France: Evolution of capacity trends by energy carrier



Source: Own illustration based on data from Kendziorski et al. (2020), Europe Beyond Coal (2022), RTE (2015-2021).

The largest part of France's power plant capacity consists of nuclear power plants with a total capacity of more than 63 GW. From 2011 to 2020 the capacity of hard coal-fired power plants decreased from approx. 8 GW to 3 GW. The capacity of gas-fired power plants increased from 7 GW to 12 GW in the same period. The data for other fossils before 2015 is contradictory, but according to the sources identified, (Kendziorski et al. 2020; Europe Beyond Coal 2022; RTE 2015-2021) this category is dominated by oil-fired power plants that decreased with the category "Other unspecified fossil fuel" from almost 13 GW in 2011 to only 4 GW in 2020.

The installed capacity of wind and solar increased from approx. 7 GW in 2011 to 26 GW in 2020, including almost 17 GW of wind and more than 9 GW of solar.

There is a traditionally high share of hydroelectric power plants in the French electricity system, amounting to around 25 GW, which decreased to less than 22 GW in 2020 according to RTE data. The capacity of biomass power plants fluctuated between approx. 1 and 2 GW.

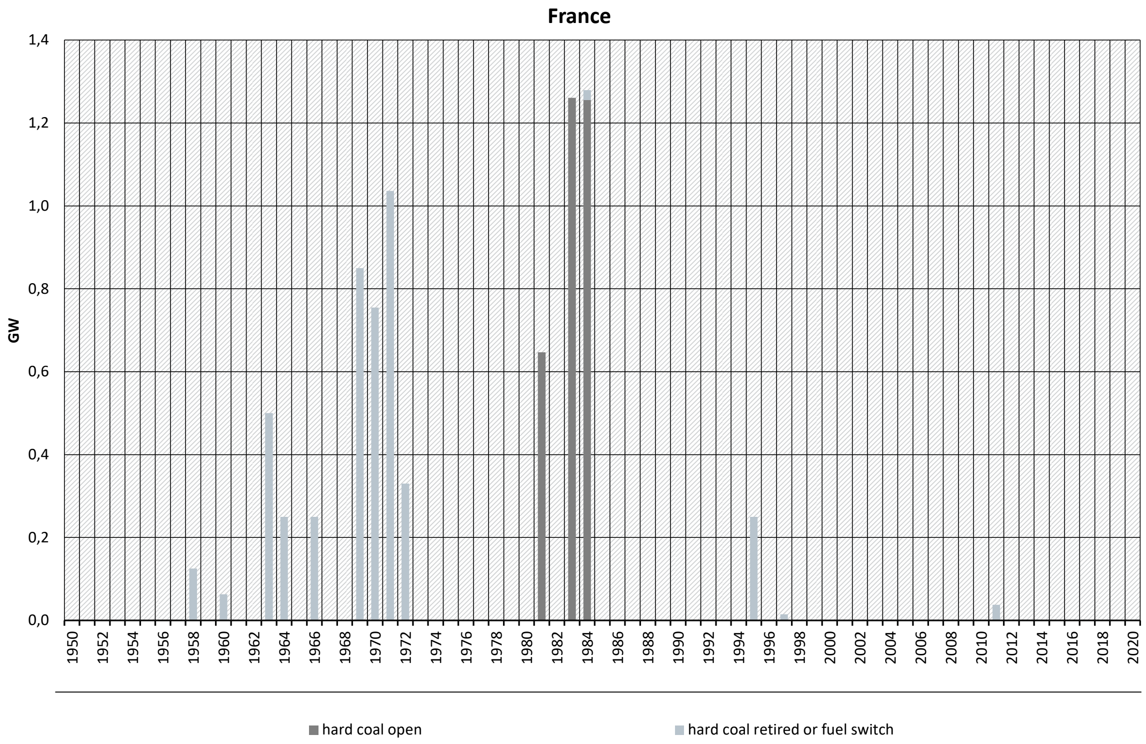
Due to the high share of nuclear and traditional hydro power in the French electricity mix, CO_2 emissions from power generation are comparatively low, as shown in Figure 27. Hard coal power plants contributed the highest share to emissions from electricity generation in the earlier years of the last decade.

Figure 29 shows the age structure of hard coal power plants in France. The graph includes coal plants that are now retired in a paler shade. The first investment wave can be observed mainly between 1963 and 1972. All power plants of this period are now retired with the exception of one small 60 MW CHP block which has undergone a switch to biomass (Lyan 2019). Most retirements took place in the years 2013 to 2015 when a combination of air pollution regulations (Julian Schwartzkopff 2015) and the start of a new EU ETS trading period (Energie-Chronik 2011) with the auctioning of allowances for electricity generation (instead of free allocation) made the continued operation of these power plants financially less attractive.

A second investment wave can be observed between 1981 and 1984. All five hard coal units still in operation were built during this period. These five units, each with around 630 MW, are Cordemais 4 and Cordemais 5, Le Havre II 4, Provence 5 and Emile-Huchet 6 and are located at four sites: in Cordemais near Nantes, in Le Havre, near Aix-en-Provence and in the Moselle department near the French-German border.

Three newer hard coal power plants from 1995 (250 MW), 1997 (15 MW) and 2011 (38 MW) are either retired or have switched fuel.

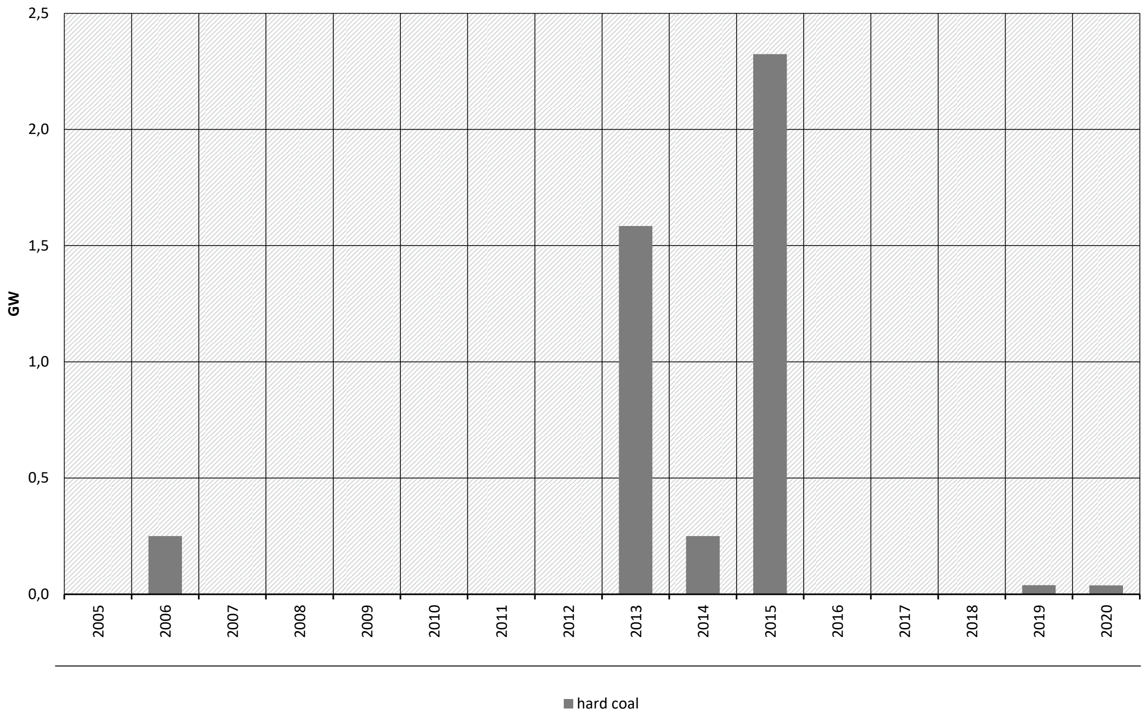
Figure 29: France: Age structure of hard coal power plants sorted by year of commissioning



Source: Own illustration based on data from Europe Beyond Coal (2022).

Figure 30 shows the decommissioning of 20 hard coal-fired power plants in France with a total of almost 4.5 GW between 2006 and 2020. 16 of those were units above 100 MW with commissioning dates between 1958 and 1972 except one unit from 1995 (Provence 4, 250 MW), which was converted to a 170 MW biomass unit in 2015 (Global Energy Monitor Wiki 2022b).

Figure 30: France: Retired coal-fired plant capacities sorted by retirement date

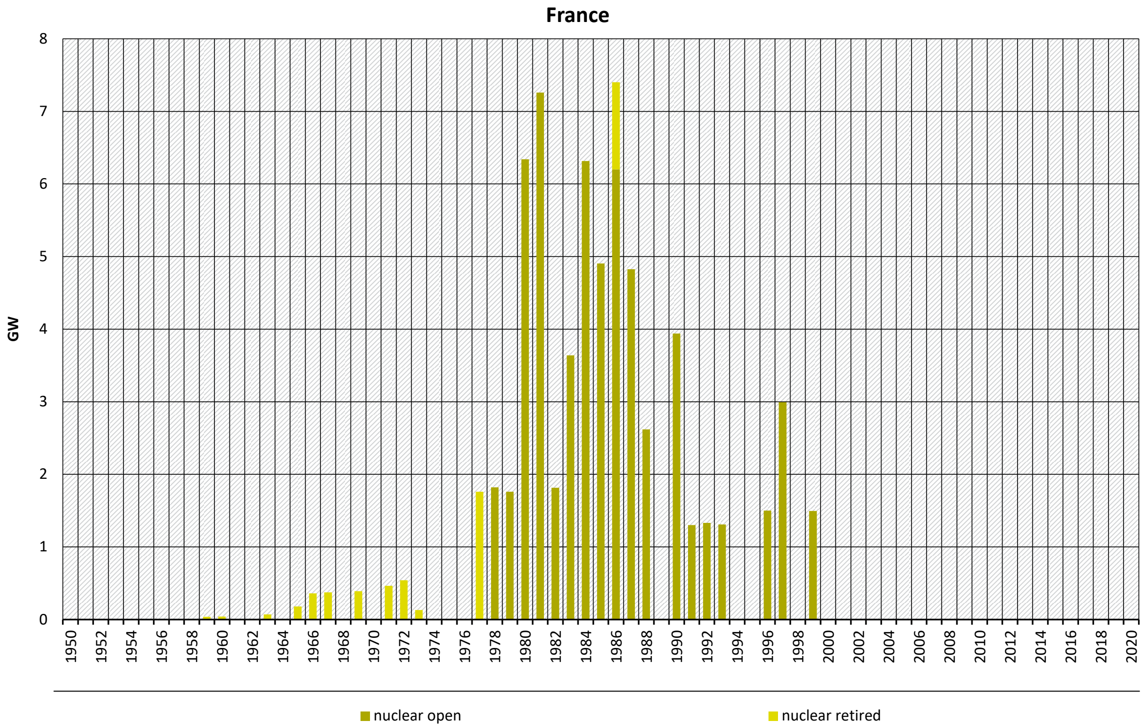


Source: Own illustration based on data from Europe Beyond Coal (2022).

As nuclear power plays a major role in the French electricity system, Figure 31 shows the age structure of French nuclear power plants, both open and decommissioned. After the first generation of nuclear reactors were connected to the grid between 1958 and 1973, with capacities ranging from 40 MW to 540 MW, the real boom of nuclear power plants began in 1977 and lasted for more than 20 years. Between 1977 and 1999, one or more nuclear power plants were connected to the grid almost every year. In 1986, the year of the Chernobyl accident, six new nuclear reactors were connected to the grid in France. They had a combined capacity of 7.4 GW, the highest capacity ever added annually.

This age structure means that in 2022, 30 % of the installed capacity still in operation is at least 40 years old. 88 % of the installed capacity in operation is at least 30 years old.

Figure 31: France: Age structure of nuclear power plants sorted by year of commissioning



Source: World Nuclear Association 2022.

5.3.2 Future capacity trends

Conventional power plants

France planned a coal phase-out by 2022. This was enshrined in an energy and climate law that was passed in July 2019. In response to the Russian invasion of Ukraine and the resulting uncertainties on the gas market, the French government decided in June 2022 to restart the 647 MW Emile Huchet coal-fired power plant in the winter of 2022-23, postponing the coal phase-out until 2023 (Europe Beyond Coal 2022).

The French NECP (Government of France 2023) cites RTE research on security of supply in the face of the planned coal phase-out, which cites the commissioning of the new nuclear reactor in Flamanville as a pre-requisite for a coal phase-out. The construction of the new EPR reactor in Flamanville is already 11 years behind the original schedule and EDF does not expect commercial operation until 2023 (Montel 2021). Currently, fueling the reactor is planned for early 2024 (Energie & Management 2023). President Emmanuel Macron announced in September 2023 that the life of the remaining coal power plants would be extended, which has further delayed the coal phase-out to 2027

Nevertheless, the French government continues to rely on nuclear power. In October 2021, Macron announced “France 2030,” a 30 billion Euro investment programme for the French economy in which nuclear power plays a central role. In particular, new reactor concepts such as Small Modular Reactors are seen as an important component.

Mining areas

Today, France imports all its coal. Hard coal was mined in France until 2004. The last mine in operation was La Houve in the Lorraine region (Euracoal 2020).

Targets for power generation based on renewable energies

The French Law on Energy Transition for Green Growth set a target of 40 % for the share of renewable energies in final electricity consumption by 2030. According to the French NECP (Government of France 2023), this is to be achieved through a mix of renewable energy sources: by 2028 hydropower is to increase to more than 26 GW, onshore wind capacity is to grow to about 33 to 35 GW, photovoltaic capacity is to increase to 35 to 44 GW, and offshore wind and marine renewables are to reach about 5 to 6 GW of installed capacity. Power generation from biomass and geothermal energy are to make smaller contributions of approx. 1 GW and 24 MW respectively.

The support schemes for renewable energies in France are mainly a feed-in tariff, a premium tariff and tenders. Additionally, tax benefits are available.

The feed-in tariff is available only for small installations or non-mature technologies (among other criteria there are for example limits of capacity like maximum 100 kW for solar panels and 500 kW for hydro and biogas plants).

The premium tariff is the main support mechanism for renewable energies except for photovoltaics for which it does not apply (RES LEGAL Europe 2019b). The premium is paid to renewable energy producers in addition to the market revenue of their sold electricity. This premium is paid for the energy produced and calculated as the difference between a reference tariff (which is similar to the feed-in tariff) and a reference market price (Ministère de la transition écologique 2021).

For installations that cannot benefit from feed-in tariff or premium tariff, there is also a competitive process, which only grants remuneration to the winner of that process. The competitive process takes place either as a classic tender procedure organised by the national regulatory authority (Commission de regulation de l'énergie, CRE) or as a so-called competitive dialogue between the Ministry for Energy and the applicants (CMS 2020b).

5.3.3 Ownership structure of coal power plants

Table 19 shows the ownership structure of the coal-fired power plants in France. Three blocks with a capacity of almost 1.9 GW are owned by EDF and account for 60 % of the French hard coal capacity still in operation. The other 40 % are two units with a capacity of almost 1.3 GW and are owned by EPH.

Table 19: France: Ownership structure of the coal-fired electricity generation fleet

	Gross generation capacity [MW]	Company's share of total coal capacity	
Owner	hard coal	share %	cum. share %
EDF	1891	60%	60%
EPH	1272	40%	100%

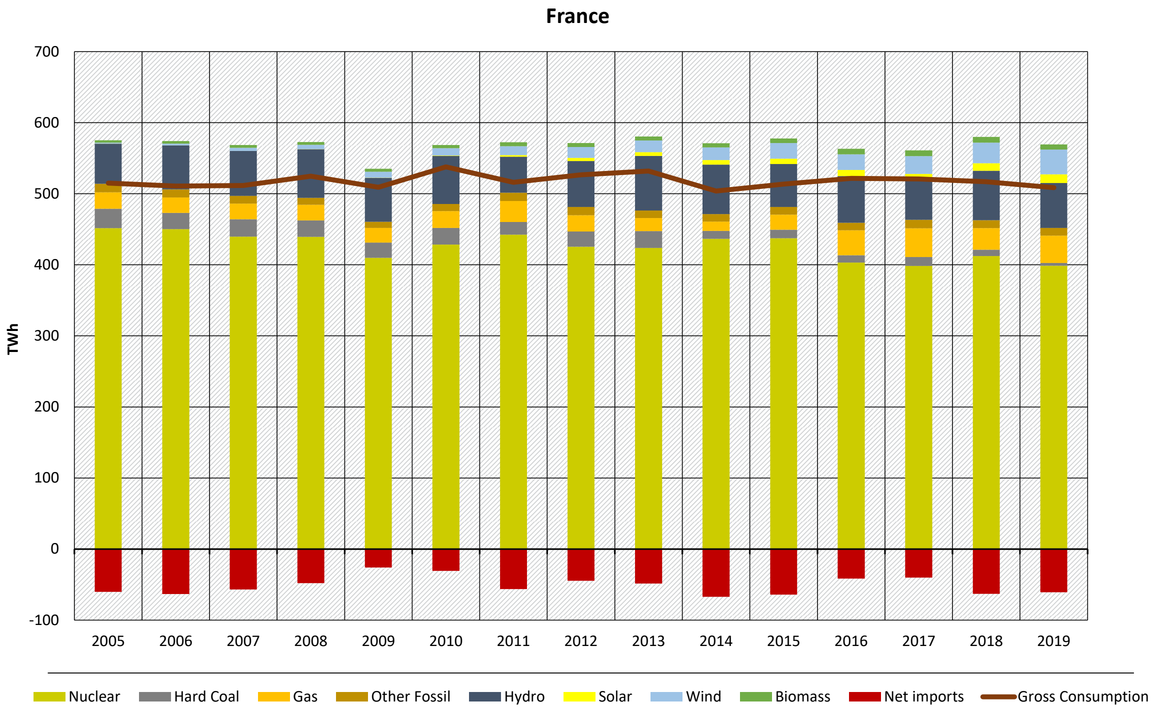
Source: Own table based on Europe Beyond Coal (2022).

5.4 Trends in electricity generation and import balance

Figure 32 shows gross electricity generation including exports from France between 2005 and 2019, broken down by fuel, as well as gross consumption.

Gross consumption is roughly stable at a level of slightly above 500 TWh over the period under consideration. In some years, slightly higher values can be observed, especially in 2008, 2010, 2012 and 2013, when consumption increased slightly.

Figure 32: France: Trends of gross electricity generation and net imports



Source: Ember (2020).

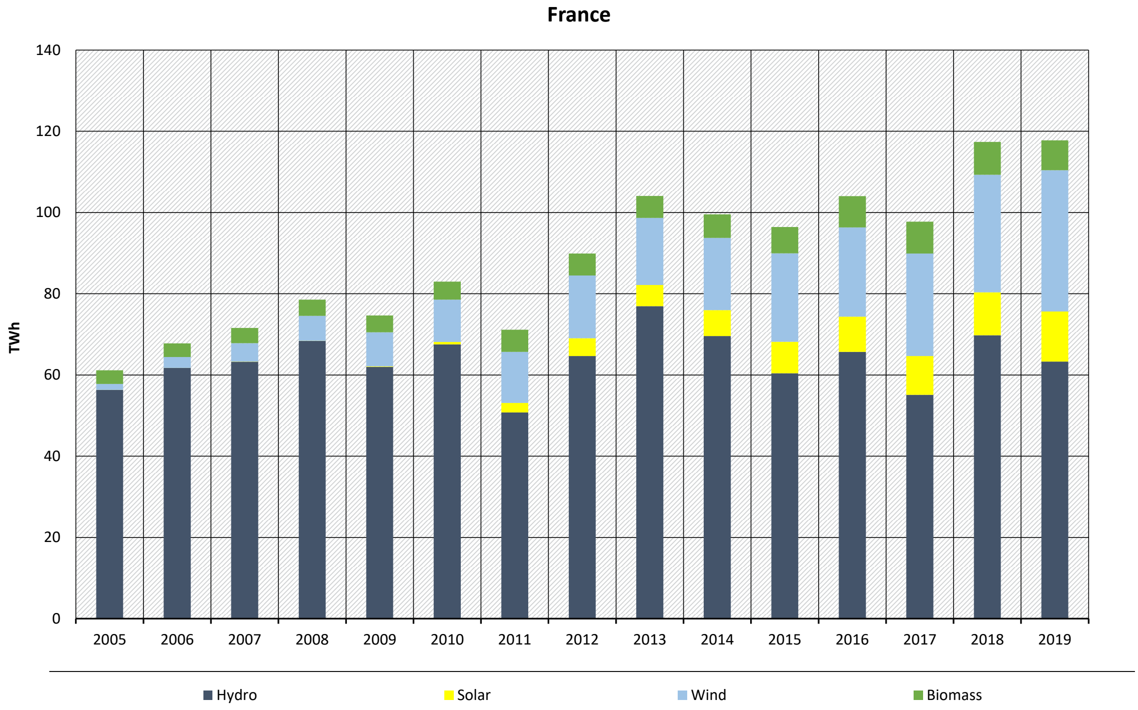
Nuclear energy provides the major share in the French electricity system. Nuclear power plants produced between 400 TWh and 450 TWh in the period considered. This comprises 70 % to almost 80 % of the domestic gross production, and between 76 % and 88 % of gross consumption.

The role of hard coal has declined in recent years. With 4 TWh in 2019, hard coal contributes almost seven times less than in 2005, when it generated 28 TWh. Electricity generation from gas power plants increased from 23 TWh in 2005 to 38 TWh in 2019. This still represents only 7 % of the electricity production in 2019. Electricity generation from other fossil fuels fluctuated at around 11 TWh.

Renewable electricity generation in France is traditionally strong in hydro power, as can be seen in Figure 33. It has provided between 50 TWh and 75 TWh in the years since 2005. The contribution of biomass has increased from about 3 TWh to about 8 TWh since 2005. There has been a large growth in wind energy, with its electricity production increasing from just over 1 TWh in 2005 to 35 TWh in 2019. Photovoltaics have played a greater role since 2011. Electricity production from photovoltaics rose from less than 1 TWh before 2011 to 12 TWh in 2019.

In 2019, hydro is still the largest renewable source of electricity with 63 TWh, wind is second with 35 TWh, solar is third with 12 TWh, and biomass is only number four with 7 TWh.

Figure 33: France: Electricity generation of renewable energies



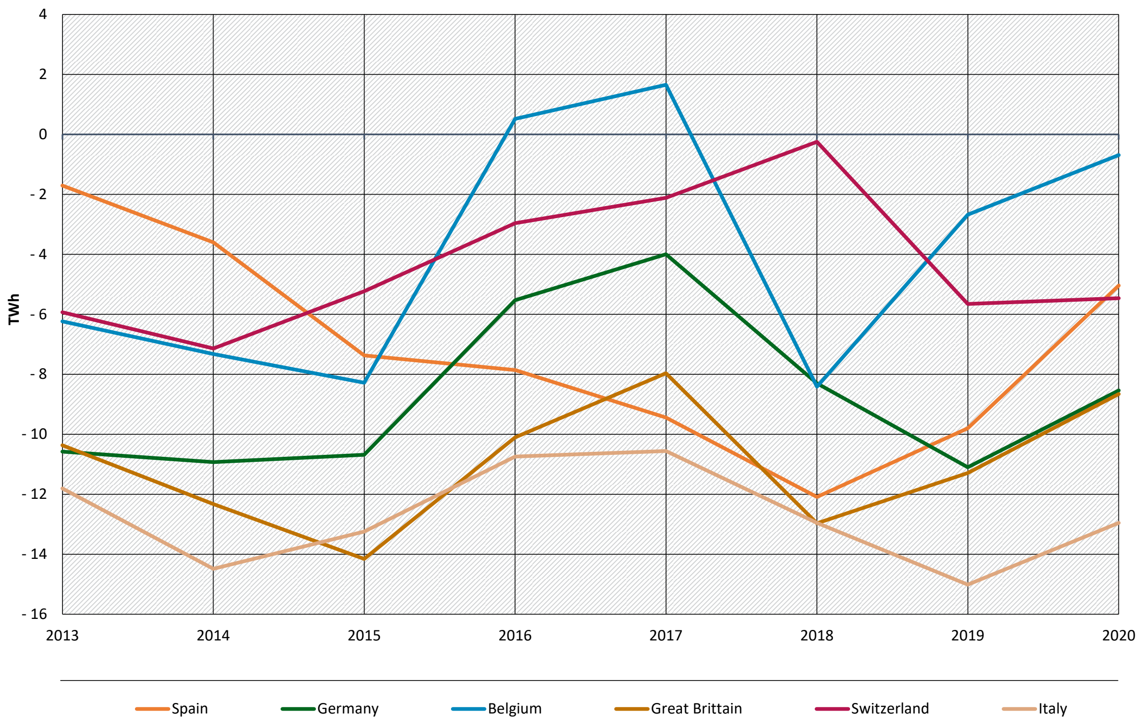
Source: Ember (2020).

Figure 32 also shows that France was continually a net exporter of electricity in terms of the annual average between 2005 and 2020. Yearly net exports vary between 26 TWh (2009) and 67 TWh (2014) in the period considered.

France is connected to Belgium, Switzerland, Germany, Spain, the United Kingdom, Italy and with a smaller transmission capacity to Luxembourg[4]. Figure 34 shows the annual net physical flows between France and its neighbouring countries for 2013 to 2020. The highest net electricity exports in the period under review, between 10 TWh and 15 TWh, went to Italy, followed by the United Kingdom, to which France exported between 8 TWh and 14 TWh. Net exports to Spain increased from 2 TWh in 2013 to 12 TWh in 2018 and decreased to 5 TWh in 2020. Net exports to Germany fluctuated between 4 and 11 TWh. Net exports to Switzerland were between almost zero and 7 TWh. Belgium is the only country from which France also imported electricity in the period shown. These imports amounted to approx. 0.5 and 1.6 TWh in 2016 and 2017. In the other years, France exported between almost zero and approx. 8 TWh to Belgium on balance.

[4] Data on the electricity exchange with Luxembourg are not available by RTE 2015-2020.

Figure 34: France: Net import (positive) and net export (negative) of electricity, physical exchange with neighbouring countries



Source: ENTSO-E 2013, 2014; RTE 2015-2020.

5.5 Market setting

5.5.1 Regional market allocation and interconnectors

The French electricity market was coupled with the Benelux countries already in 2006. The UK, the Nordic countries (Poland, Baltic states, Finland, Sweden, Norway) and Spain, Portugal, Italy and Slovenia joined in 2014 and 2015. Germany and Austria followed in 2020.

There are two Nominated Electricity Market Operators active in France: EPEX Spot SE and Nord Pool EMCO AS. Both offer day-ahead and intraday trading.

The French price zone is interconnected with neighbouring countries: Belgium, Switzerland, Germany, Spain, Italy and the UK, as shown in Table 20 based on the forecasted transfer capacity.

Table 20: France: Maximum forecasted transfer capacity with neighbouring countries in 2021 (MW)

		BE	CH	DE[1]	ES	IT	UK
FR	to	1800	2385	4810	3000	1818	2000
FR	from	600	1800	5820	2800	995	2000

Note: [1] For Germany, the values are reported for 2020 based on BNetzA; BKartA 2022

Source: Own data based on ENTSO-E.

5.5.2 Electricity market design with reference to conventional power generation plants

France introduced a capacity mechanism in 2017. Every electricity supplier is obliged to provide proof that consumption can be covered even in peak load situations. This proof is based on capacity guarantee certificates. An operator can either use capacity guarantees it holds for its own power plants or controllable loads or buy such guarantees from other operators. The required number of such capacity guarantees for an operator is based on calculations by the transmission system operator RTE. It is also RTE that releases the capacity guarantees in a certification procedure. The European Union has made it a condition to have a tender procedure for applying capacities. CO_2 emissions must be less than 200 g CO_2/MWh (Government of France 2023).

6 Germany

6.1 Key messages

- In 2019, combustion installations (Activity Code 20) in Germany emitted 245 Mt CO_2, which made Germany the largest emitter (26 %) in this category. Electricity producers account for 95 % of emissions under this category. Between 2013 and 2019, emissions from electricity generators decreased by 33 %.
- By 2019, Germany has a diverse generation mix. Lignite and hard coal-fired generation comprises 19 % and 9 % respectively. While the latter declined by 55 % between 2013 and 2019, the former decreased by 29 %. More than 55 % of the coal-fired generation fleet was installed before 1990. Gas-fired generation has a share of 15 % in 2019, increasing by 35 % since 2013. Nuclear generation decreased its share substantially between 2005 and 2019 from 26 % to 12 %. In 2018 and even more so in 2019, coal-fired generation was compensated by an increasing gas-fired and wind generation, and a reduction in exports. Assessments of the fuel switch potential show that between the end of 2018 and mid-2021, marginal generation costs of natural gas-fired power plants where below those of hard coal-fired ones.
- Electricity supply from renewables has a share of 40 % in 2019 and increased by 66 % between 2013 and 2019. The plan to increase this share to 80 % by 2030 builds on a strong expansion of wind and solar PV capacities. Biomass-based generation increased up to 2015 and has been stable since then.
- Due to the prominent role of coal in electricity generation in Germany, the average emission factor of gross electricity generation is about 0.4 Mt CO_2 per MWh which is 60 % higher than the EU-28 average emission factor in 2019.
- Germany is a net exporter of electricity in the Central European electricity system and is well integrated with its neighbouring countries. Internal grid bottlenecks between the North and the South are not reflected in the market design and have led to loop flows in Poland and the Czech Republic.
- A coal phase-out is enacted by the end of 2038, with defined intermediate steps in 2022 and 2030. Nuclear was phased-out in April 2023.

Table 21: Germany: Key figures on the electricity sector in 2019

	2019	% change compared to 2013
	CO_2 emissions	
Total CO_2 emissions in 2019 from ETS Activity Code 20 (share of EU-28)	245 Mt CO_2 (26%)	-32%
Total CO_2 emissions from electricity producers[1] (share of combustion installations in the country)	234 Mt CO_2 (95%)	-33%
Emission factor of gross electricity production[2] (relative to EU-28 average)	0.39 t CO_2/MWh (161%)	-30%
	Gross electricity generation	
Total (share of total EU-28)	605 TWh (19%)	-4%
Net electricity imports	-37 TWh	14%
Lignite share in gross generation (share of total gross lignite-fired generation in EU-28)	19% (45%)	-29%
Hard coal share in gross generation (share of total gross hard coal-fired generation in EU-28)	9% (26%)	-55%
RES share in gross generation (target for 2030)[3]	40% (80%)	66%
	Installed capacity	
Total lignite-fired capacity installed (share of total EU-28)	19.9 GW (37%)	-11%
Share of lignite-fired capacity installed before 1990 (share of total EU-28)	49% (20%)	-20%
Total hard coal-fired capacity installed (share of total EU-28)	25.4 GW (26%)	-12%
Share of hard coal-fired capacity installed before 1990 (share of total EU-28)	57% (27%)	- 18%

Note: Note: [1] CO_2 emissions from electricity producers based on power plants identified in Oeko-Institut's EU ETS database. [2] Emission factor calculated based on CO_2 emissions by power plants identified in Oeko-Institut's EU ETS database and gross electricity production reported by Ember (2020). [3] According to Article 4 (2) Regulation (EU) 2018/1999, MSs have to provide information on their contribution to the Union's binding renewable energy target of at least 32% expressed as renewable energy share on gross final energy consumption. They do so in their NECPs (Article 3(2)(b)). Along with this contribution they also have to report on *estimated trajectories for the sectoral share of renewable energy in final energy consumption from 2021 to 2030 in the electricity, heating and cooling, and transport sector* (see Annex I Regulation (EU) 2018/1999 which sets out the structure of the NECPs).

Source: Own table based on EC n.d., Europe Beyond Coal (2022), Ember (2020), and EEA (2021).

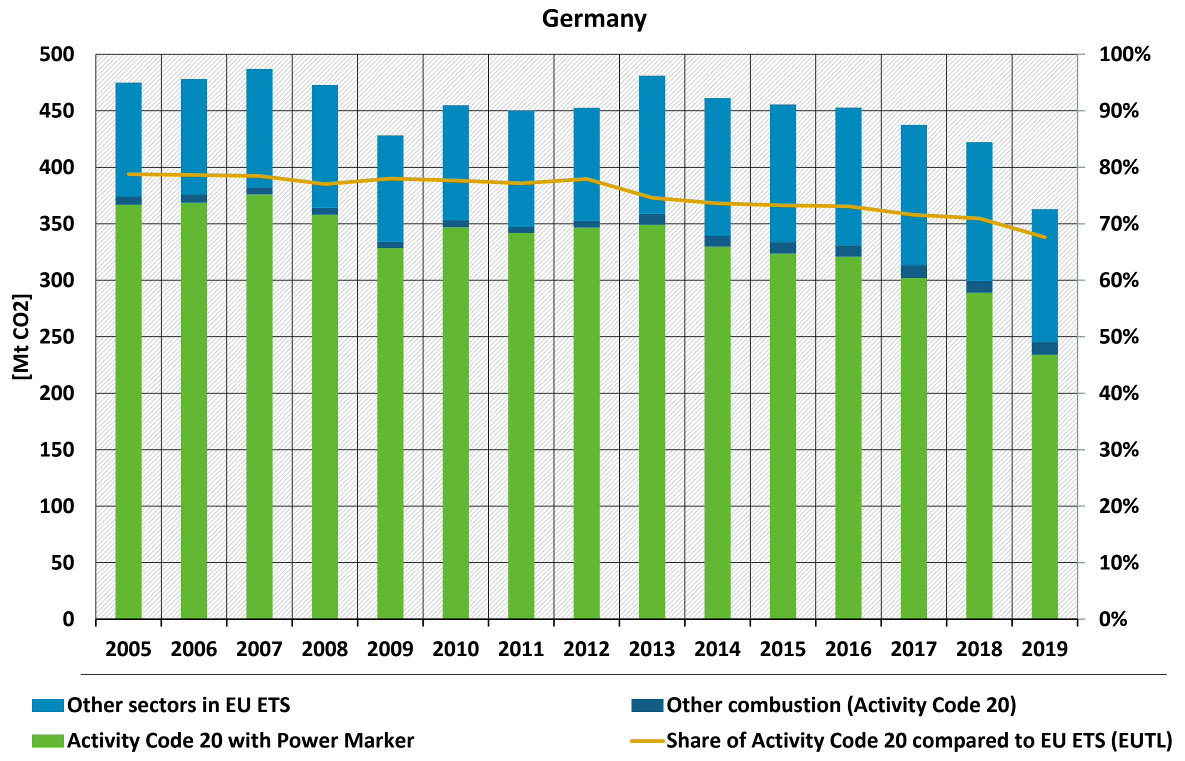
6.2 Emission trends in the EU ETS (combustion installations)

Figure 35 shows CO_2 emissions under the EU ETS in Germany from 2005 to 2019. CO_2 emissions from combustion installations accounted for between 68 % and 79 % of total emissions and consisted mainly (about 98 %) of emissions from power plants.

EU ETS emissions were roughly constant at around 480 Mt CO_2 from 2005 to 2008. After this, there was a decline in 2009 and subsequent years. In 2013, emissions were back at a similar level to 2005. Since then, CO_2 emissions in the EU ETS have been falling, reaching a minimum of 363 Mt in 2019 (minus 24 % compared to 2005).

CO_2 emissions from combustion installations (Activity Code 20), showed a slightly stronger decrease (minus 34 % from 374 Mt in 2005 to 245 Mt in 2019) than the other activities.

Figure 35: Germany: Emission trends in the EU ETS



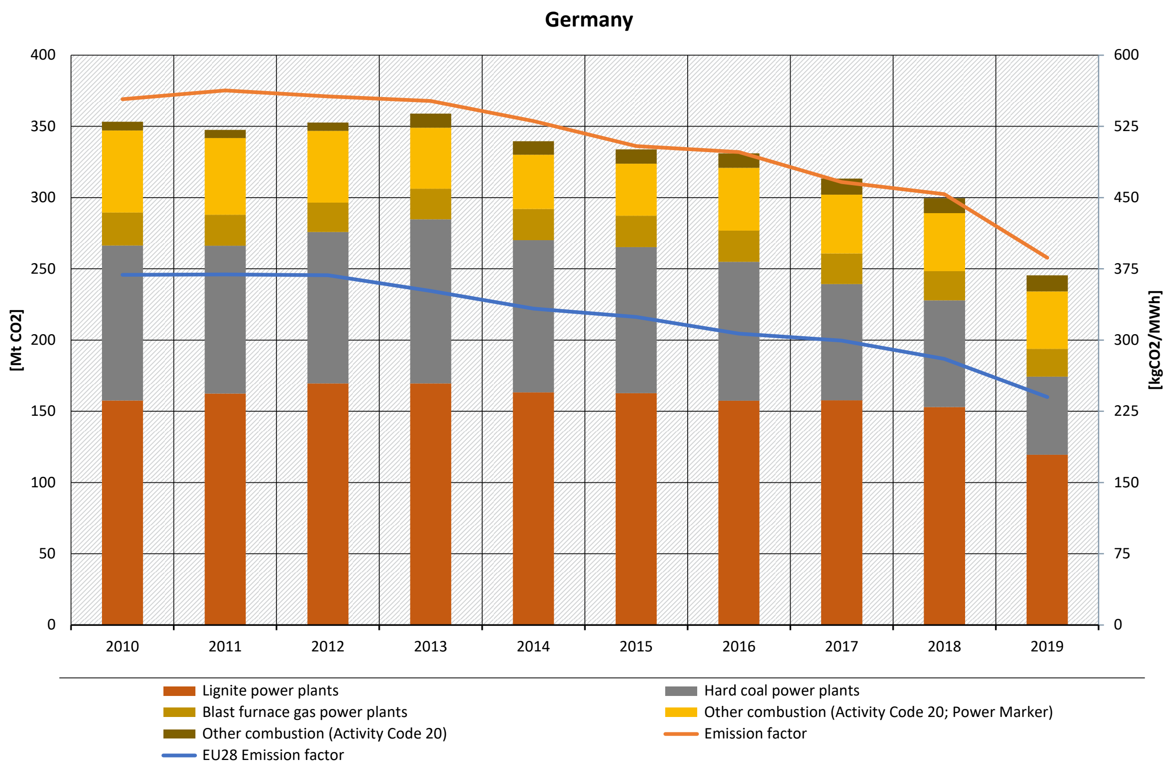
Source: Own compilation of data based on EC n.d., and EEA (2021).

Figure 36 details the combustion emissions by fuel and thereby shows the origin of this decrease in 2019. Emissions from hard coal-fired generation decreased from about 110 Mt CO_2 between 2010 and 2015 to only 55 Mt CO_2 in 2019. Lignite-fired generation accounted for the largest share of CO_2 emissions, with an almost constant block of about 160 Mt CO_2 in the years 2010 to 2018. In 2019, CO_2 emissions from lignite fell to 120 Mt CO_2.

CO_2 emissions from blast furnace gas power plants remained roughly constant. CO_2 emissions from other power plants decreased from 60 Mt to 40 Mt between 2010 and 2019.

Figure 36 also includes a comparison between the average EU-28 and the German emission factor. The German emission factor decreased slightly less in the given period. In 2010, the German emission factor was 595 kg CO_2/MWh, 1.4 times higher than the European one. In 2019, it was 387 kg CO_2/MWh, which is 1.6 times higher than the EU-28 average.

Figure 36: Germany: Emission trends in Activity Code 20



Note: Emissions in the category: other combustion (Activity Code 20; Power Marker) are calculated using the deduction method: All emissions with Power Marker minus emissions from lignite and hard coal-fired power plants minus emissions from blast furnace gas power plants.
Source: Own illustration based on data from Europe Beyond Coal (2022), EEA (2021), Ember (2020), and own assignment based on EC n.d..

6.3 Capacity trends

6.3.1 Existing capacities

Figure 37 shows the development of the installed gross capacity of German power plants from 2005 to 2020.[5]

The capacity of hard coal-fired power plants declined from 29 GW in 2005 to about 25 GW in 2012. Due to the construction of new hard coal power plants, it rose again to 29 GW in 2015. The subsequent decommissioning of hard coal-fired power plants resulted in an installed capacity of about 23 GW in 2019, which increased to about 24 GW in 2020 due to the commissioning of one new hard coal block.

The capacity of lignite-fired power plants was 22 GW in 2005. With some minor fluctuations, the capacity fell to about 20 GW in 2020.

The capacity of nuclear power plants decreased within the framework of the phase-out path decided by the government: between 2005 and 2010 the capacity amounted to 21.5 GW; it was reduced to 12 GW after the Fukushima accident in 2011. Additional closures reduced the

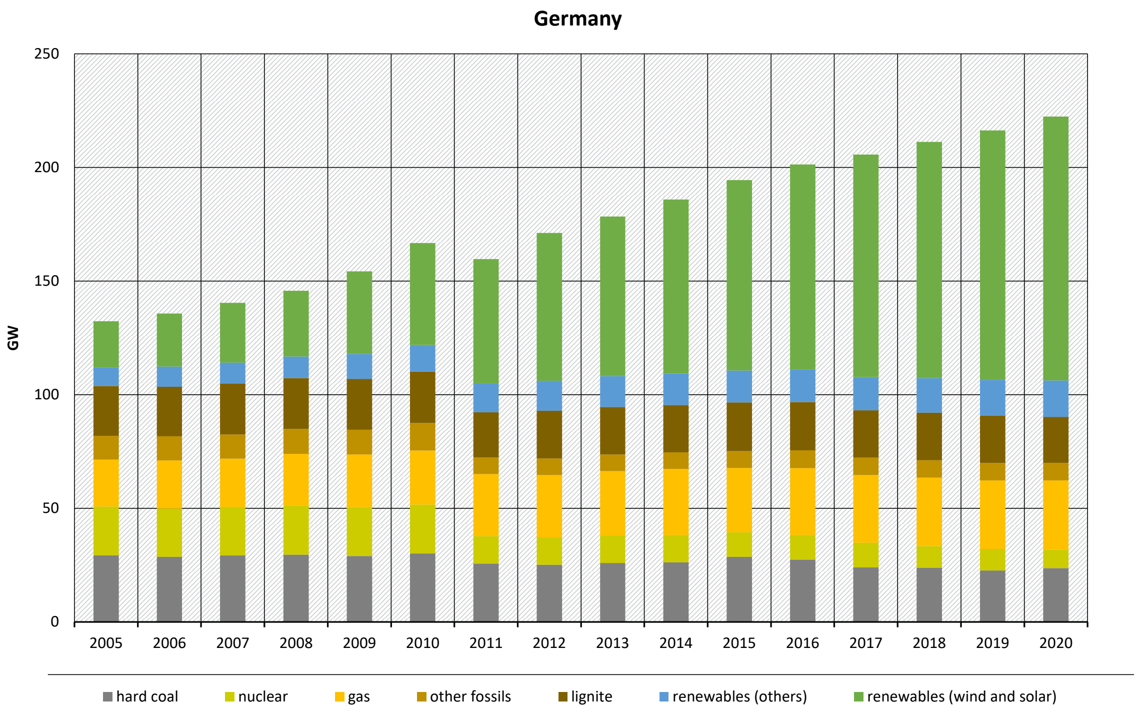
[5] Figures refer to gross capacity and are thus higher than the figures shown in the key messages section at the beginning of the chapter as these relate to net capacity.

capacity to almost 11 GW between 2015 and 2017, to 9.5 GW in 2018 and 2019 and to 8 GW in 2020.

Gas power plants increased their capacity from 21 GW in 2005 to 31 GW in 2020.

The capacity of other fossil fuel-fired power plants fell from approx. 11 GW in 2005 to 2010 to approx. 7.5 GW in 2011 to 2020.

Figure 37: Germany: Evolution of gross capacity by energy carrier



Source: BMWi 2021, AGEE-Stat 2021.

The renewable capacity by wind and solar plants increased from 20 GW in 2005 to 116 GW in 2020.

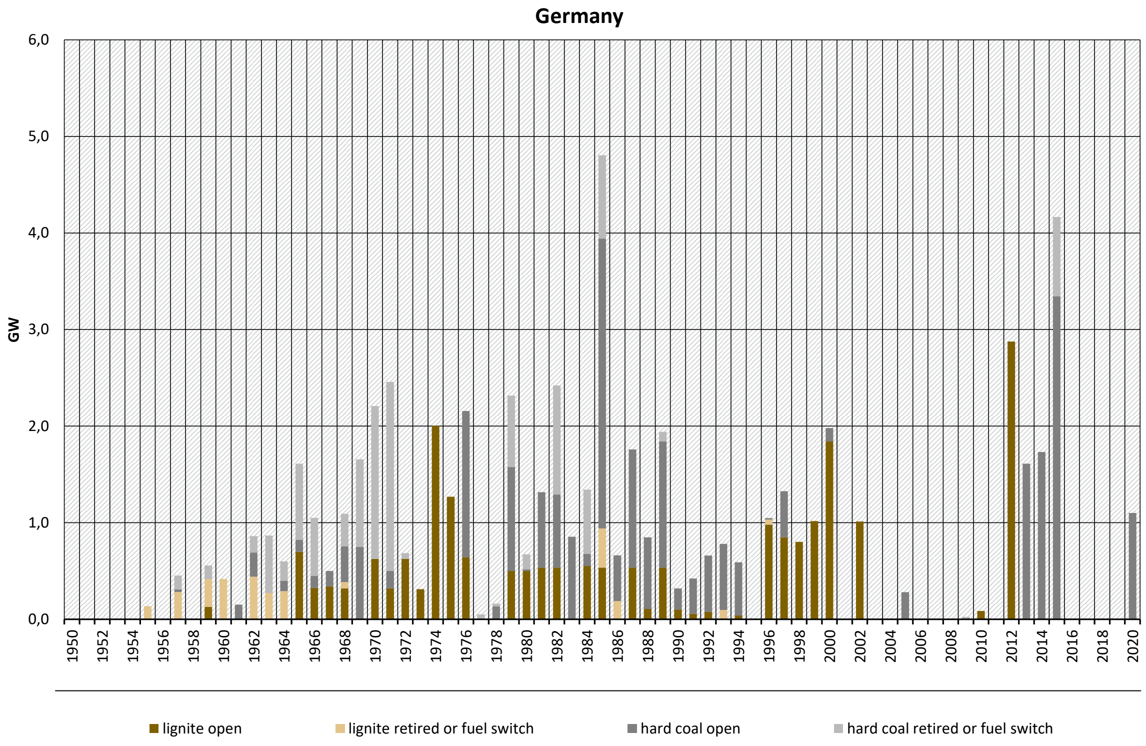
The other renewable category in Figure 37 includes hydropower plants as well as biomass-fired plants (including biogenic waste) and geothermal power plants. In 2005, there were 8 GW of such plants, their capacity doubled to 16 GW in 2020.

The comparison between Figure 36 and Figure 37 shows that coal power plants account for about a third of the installed capacity in the period around 2010, they are responsible for about 80 % of power plant emissions. Figure 38 therefore takes a closer look at the German lignite and hard coal power plants by detailing their age structure. The graph includes coal plants that are retired by now in a paler shade. The following can be observed:

- There was a first investment wave from the 1950s to the mid-1970s: In those years almost 10 GW of lignite power plants and 11 GW of hard coal power plants were installed.
- In the period between 1977 to 1995, hard coal dominated the new coal power plants with capacities of 16 GW for hard coal and 5 GW for lignite.

- From 1996 to 2005, mainly new lignite-fired power plants were commissioned: 6.5 GW in total, of which 5.5 GW were new lignite-fired power plants in eastern Germany. Only 0.9 GW of hard coal capacity was installed during these years.
- After some years without new coal power plants, new investments were made between 2010 and 2020: these relate to 10 hard coal power plants with a combined capacity of 8.6 GW. One of these blocks could not be put into operation due to technical problems (see below), leaving 9 blocks with a total of 7.8 GW to be commissioned. In the same period, four lignite blocks with a total capacity of almost 3 GW were installed.

Figure 38: Germany: Age structure of lignite and hard coal power plants sorted by year of commissioning



Source: Own illustration based on data from Europe Beyond Coal (2022).

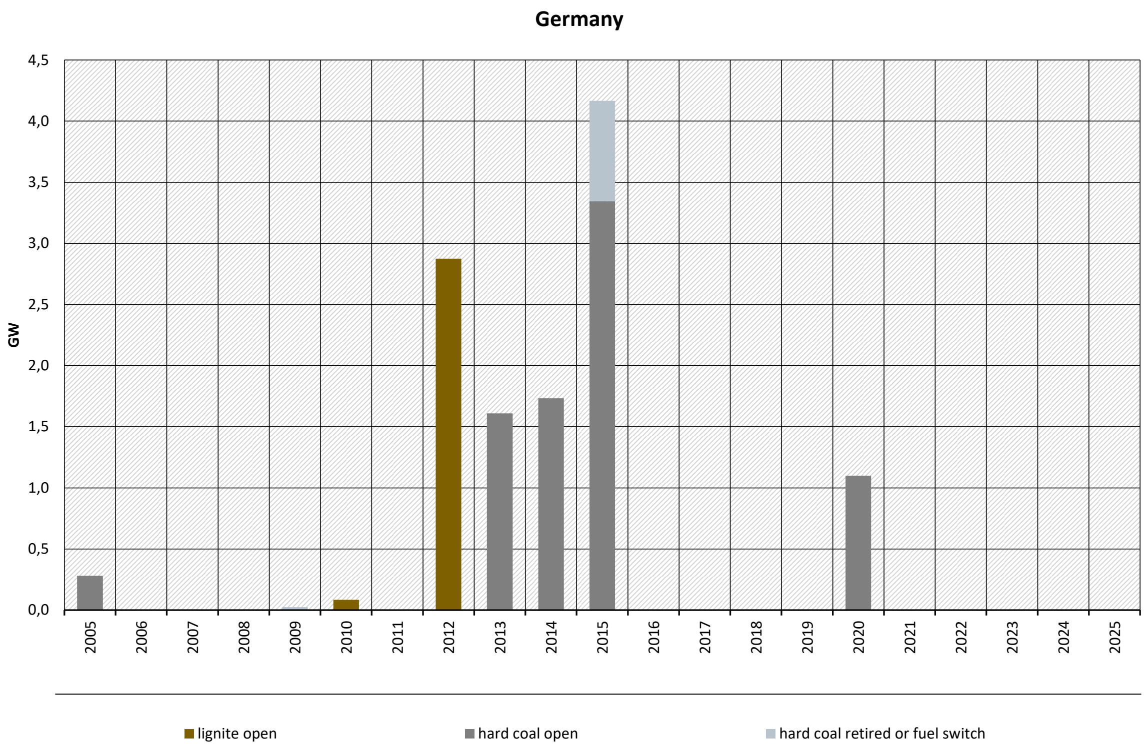
Figure 39 shows the age structure of only the newer coal power plants with a commissioning year of 2005 or younger and power plants under construction.

After a fuel-switch in 280 MW block in Mannheim in 2005, more hard coal came online in 2013, 2014 and 2015: There were two 800 MW blocks in Duisburg (Walsum) and Luenen in 2013, two new blocks (800 and 900 MW) in Hamm and Karlsruhe in 2014 and five blocks of the same size in 2015. One of these five power plants was the 800 MW Unit D in Hamm, where hydrochloric acid entered the boiler circuit due to a technical breakdown. As the economic damage was too great, the power plant was not put into operation. The other four hard coal blocks commissioned in 2015 are situated in Mannheim, Hamburg (two blocks) and Wilhelmshaven.

The newest addition to the German coal power plant fleet is the 1100 MW block Datteln 4 which came online in 2020. Construction had already started in 2007, but strong protests by environmentalists, court rulings against the commissioning and technical problems led to delays.

After 2005, the only lignite power plants constructed in Germany (besides a small 85 MW block installed in 2010) were one 675 MW block in Boxberg and two 1100 MW blocks in Grevenbroich-Neurath, all of which were constructed in 2012.

Figure 39: Germany: New lignite and hard coal power plants since 2005 including plants under construction sorted by year of commissioning

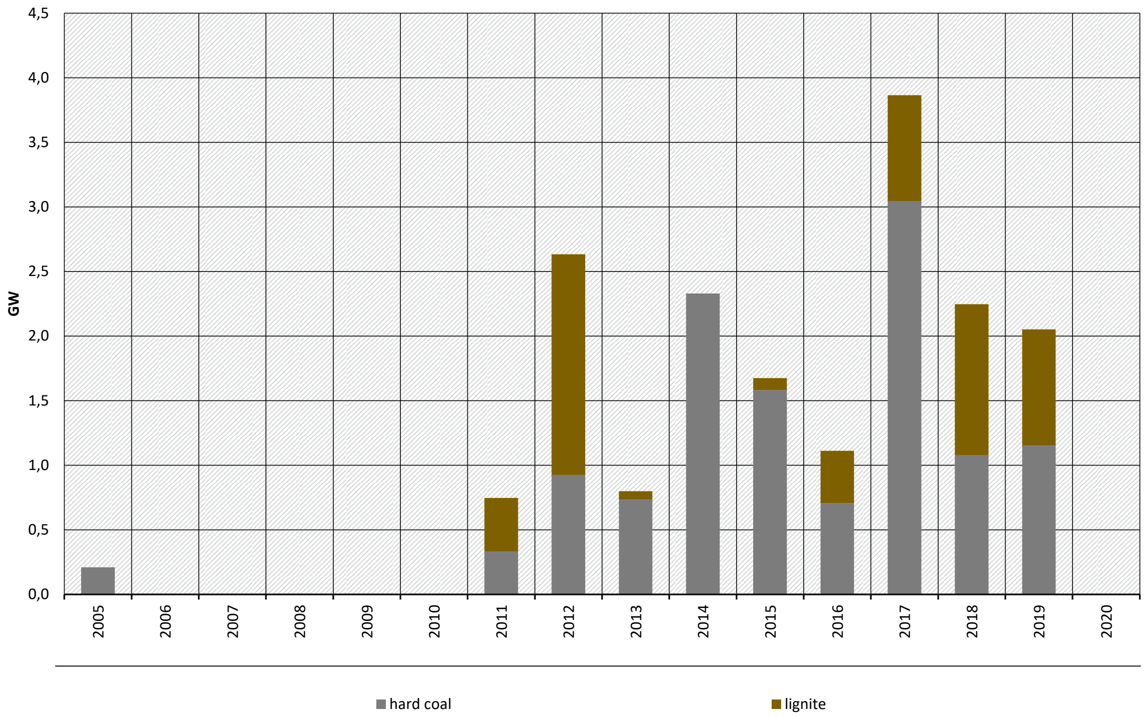


Source: Own illustration based on data from Europe Beyond Coal (2022).

Figure 40 shows the retired coal-fired plants in Germany since 2005. After the decommissioning of five small hard coal blocks in Münster and in Halle, retirements took place between 2011 and 2019. In this period, 47 hard coal blocks with a total capacity of almost 11.9 GW and 27 lignite blocks with a total capacity of almost 5.6 GW were retired.

The lignite units include eight lignite blocks with a total capacity of 3 GW, which have been gradually transferred to "security reserve" by law since 2016. They can be reactivated in case of emergency within ten days. Three of these plants have already been permanently decommissioned. The remaining five, which have a total capacity of 1.8 GW, were originally scheduled for final decommissioning in autumn 2022 and 2023. However, in response to the Russian invasion of Ukraine and the associated uncertainty on the energy markets, the German government postponed the final decommissioning until the end of March 2024 to allow these power plants to return to the electricity market in an emergency.

Figure 40: Germany: Retired coal-fired plant capacities (including lignite plants in security standby) sorted by retirement date



Source: Own illustration based on data from Europe Beyond Coal (2022).

6.3.2 Future capacity trends

Conventional power plants

In July 2020, the Bundestag and the Bundesrat adopted the Act on the Phase-out of Coal-fired Power Plants after an expert and stakeholder commission had recommended a phase-out plan for coal-fired power generation. This law provides for a gradual phase-out of electricity generation from hard coal and lignite by 2038 at the latest. In a first step, the capacity of hard coal and lignite power plants is to be reduced to 15 GW each by 2022. By 2030, 8 GW of hard coal and 9 GW of lignite power plants are permitted. The construction of new coal power plants is forbidden (Bundesregierung 2020). The new government elected in 2021 formulated in its coalition agreement the intention to "ideally bring forward" the coal phase-out to 2030 (BReg 2021).

Nuclear energy was planned to be phased out by end of 2022, as foreseen in the Atomic Energy Act following the decisions taken in the aftermath of the Fukushima reactor accident in 2011. After the reductions of nuclear capacity described above, three more power plants had been shut down by the end of 2021, leaving the last three nuclear power plants to be closed by the end of 2022 (AtG 1959). In order to increase available generation capacity in the peak of the energy crisis induced by the Russian invasion into Ukraine, the shutdown of the last three reactors was postponed to April 15th, 2023 (Deutscher Bundestag 2022). Since April 16th 2023 there are no more active commercial nuclear reactors in Germany (BMUV 2023).

Mining areas

Germany's hard coal production ended in 2018 after the government phased out all state aid for domestic hard coal mining.

However, there is still lignite production in the three lignite mining areas in Germany: the Rhenish mining area around Cologne, Aachen and Mönchengladbach, the Lusatian mining area in south-eastern Brandenburg and north-eastern Saxony, and the Central German mining area in the south-east of Saxony-Anhalt and the north-west of Saxony.

In 2020, 107 Mt of lignite was produced (compared to 166 Mt in 2018). Existing mines contained reserves of 1 686 Mt at the end of year 2020 and were thus 16 times larger than the annual production in 2020 (Hermann and Matthes 2022). As lignite is mainly used for electricity generation, further mining depends on the new and probably accelerated coal phase-out path to be decided by the new government.

Targets for power generation based on renewable energies

The initial German NECP envisaged a 65 % share of renewable energies in gross electricity consumption in 2030. The main legal framework is the Renewable Energy Sources Act which provides payments for electricity produced from renewables either as a feed-in tariff (for small installations) or as an auction-based premium that is additional to the market revenue.

According to the coalition agreement of the government elected in 2021 and the updated Renewable Energy Sources Act for 2023, however, the share of renewable energies in gross electricity consumption is to be increased to 80 % in 2030, while at the same time gross electricity consumption is assumed to increase to 680 TWh to 750 TWh. This results in a target of 544 TWh to 600 TWh of renewables-based electricity generation in 2030. For comparison: in 2020, renewable electricity production was at 250 TWh, which corresponded to 45 % of gross electricity consumption in that year.

6.3.3 Ownership structure of coal power plants

Table 22 summarizes the ownership structure of lignite- and hard coal-fired generation capacity by company based on the situation in 2020. With 31 % RWE holds the largest share of all coal capacities, followed by EPH with 17 %. Uniper owns 11 % of the coal capacities, followed by STEAG and EnBW, each of which own 9 %. While the larger lignite-fired power plants are owned by only four companies, the picture is somewhat more mixed for hard coal-fired power plants, which are often owned by municipal utilities. Therefore, the list includes 29 different owners of coal-fired power plants.

Table 22: Germany: Ownership structure of the coal-fired electricity generation fleet

Owner	Gross generation capacity by fuel type [MW]		Company's share of total coal capacity	
	lignite	hard coal	share (%)	cumulative share (%)
RWE	10970	3804	30%	30%
EPH[6]	7293	750	18%	48%
Uniper	980	4180	12%	59%

[6] At the lignite-fired Lippendorf site, EPH owns block R while EnBW own block S.

	Gross generation capacity by fuel type [MW]		Company's share of total coal capacity	
STEAG	0	4450	10%	70%
EnBW[6]	934	4434	12%	82%
Vattenfall	0	2340	5%	87%
Riverstone	0	1649	4%	91%
Trianel Kohlekraftwerk Lünen GmbH & Co. KG	0	820	2%	92%
City of Hamburg	0	495	1%	94%
swb AG	0	455	1%	95%
Volkswagen AG	0	446	1%	96%
Stadtwerke München GmbH	0	365	1%	96%
Versorgungs- und Verkehrsgesellschaft Hannover mbH (VVG)	0	300	1%	97%
Currenta GmbH & Co. OHG	0	260	1%	98%
City of Chemnitz	167	0	0%	98%
Stadtwerke Frankfurt am Main Holding	0	144	0%	98%
Evonik	0	136	0%	99%
City of Flensburg	0	100	0%	99%
Stadtwerke Köln GmbH (100% City of Cologne)	85	0	0%	99%
Stadtwerke Cottbus GmbH	82	0	0%	99%
Veolia	0	78	0%	99%
MVV Energie AG	0	60	0%	100%
City of Frankfurt (Oder)	49	0	0%	100%
City of Kassel	38	0	0%	100%
SWP Stadtwerke Pforzheim GmbH & Co. KG	0	30	0%	100%
GKS Gemeinschaftskraftwerk Schweinfurt GmbH	0	29	0%	100%
City of Erlangen	0	18	0%	100%
SWK - Stadtwerke Kaiserslautern	0	15	0%	100%

Source: Own table based on Europe Beyond Coal (2022).

6.4 Trends in electricity generation and import balance

Figure 41 shows the gross electricity generation in Germany between 2005 and 2019, broken down by fuel, as well as gross consumption and net exports.

Gross consumption amounts to approx. 600 TWh in the above-mentioned period, with a decrease in 2009 due to the economic crisis and a very slight downward trend in recent years. Germany was a net exporter of electricity in the entire period from 2005 to 2019.

Electricity generation from nuclear power plants declined due to the German phase-out decision following the accident in Fukushima. In 2005, approx. 160 TWh were generated from nuclear power plants; in 2019, it was only 75 TWh.

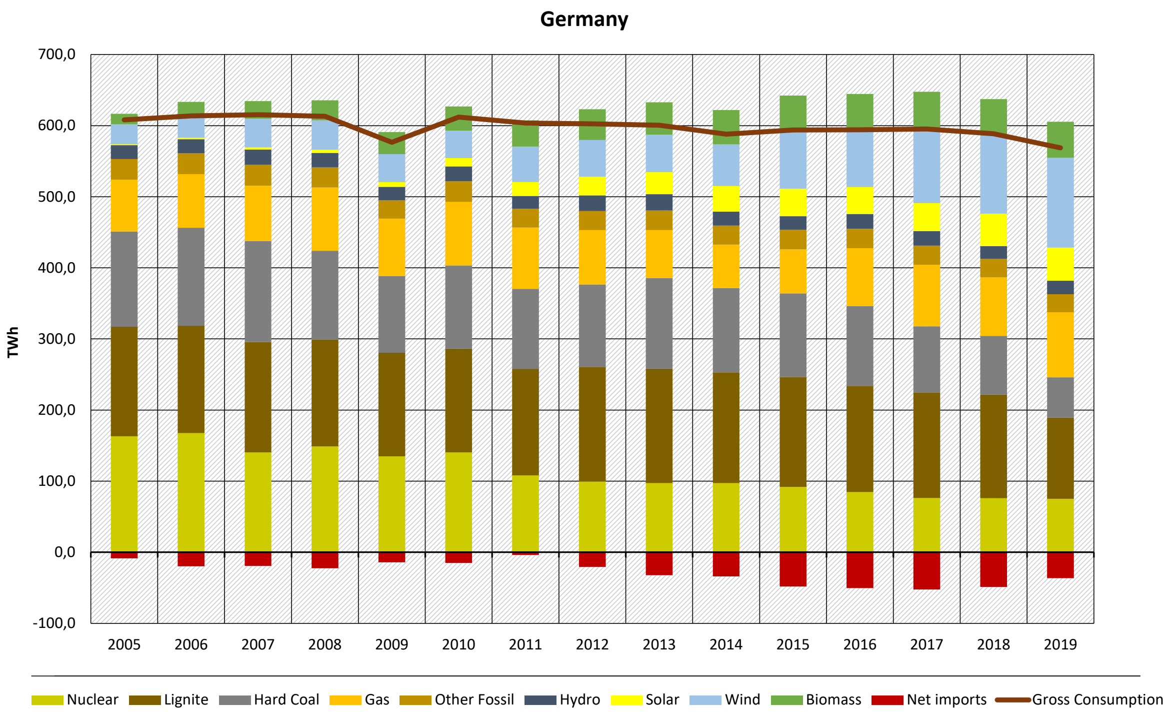
Lignite power plants provided between 145 TWh and 160 TWh in the years 2005 to 2018. A more substantial decline is observed in 2019 when lignite power plants generated 114 TWh, only.

Generation from hard coal-fired power plants declined substantially over time: from around 140 TWh in the first years of the period to less than 60 TWh in 2019.

Electricity generation from gas-fired power plants shows the greatest fluctuations. From approx. 70 TWh in 2005, it rose to almost 90 TWh in 2008 and 2010. In the following years, it fell to a minimum of just over 60 TWh in 2014 and increased to more than 90 TWh in 2019.

Electricity from other fossil fuels shows a slight downward trend from 29 TWh in 2005 to 26 TWh in 2019.

Figure 41: Germany: Trends of gross electricity generation and net imports



Source: Ember (2020).

The yearly assessment of the fuel switch potential by the German Environment Agency (Deutsche Emissionshandelsstelle (DEHSt) im Umweltbundesamt 2019; 2020; 2021; DEHSt 2022; 2023) shows that between the end of 2018 and mid-2021, CO_2 prices in combination with relatively low natural gas prices reduced the profitability of hard coal-fired power plants such that it was more economical to generate electricity in natural gas-fired power plants. Lignite power plants benefit from comparably low and stable costs for their fuel. Nevertheless, in early

2021, high CO_2 prices also led to negative profit margins for lignite power plants. The situation changed drastically in the second half of 2021 when natural gas prices rocketed in relation to increasingly tightened supply and the subsequent Russian invasion of Ukraine – despite high CO_2 prices, coal-fired power plants were more economical than natural gas-fired units.

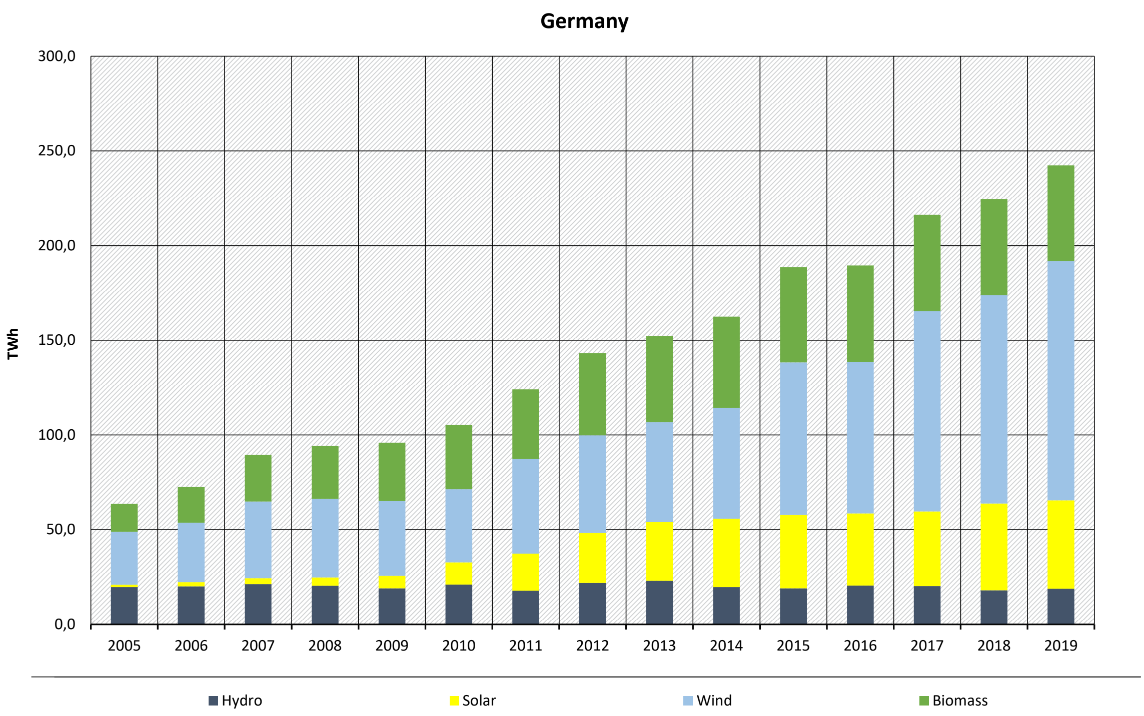
Electricity generation from the main renewable energy sources in Germany increased from 63 TWh in 2005 to 242 TWh or 40 % of the electricity production in 2019 (Figure 42).

Wind-based generation including electricity from onshore and offshore wind turbines increased from 28 TWh in 2005 to 126 TWh in 2019. It represents the largest share of renewable electricity in 2019. Biomass was number two in 2019 with 50 TWh; in 2005 it was used to produce only 15 TWh.

Solar energy-based generation delivered 47 TWh in 2019 and had the largest growth since 2005, when solar panels generated only 1 TWh.

Electricity from hydro power is a traditional form of renewable electricity generation in Germany. It varied between 18 TWh and 23 TWh in the period under consideration.

Figure 42: Germany: Electricity generation of renewable energies

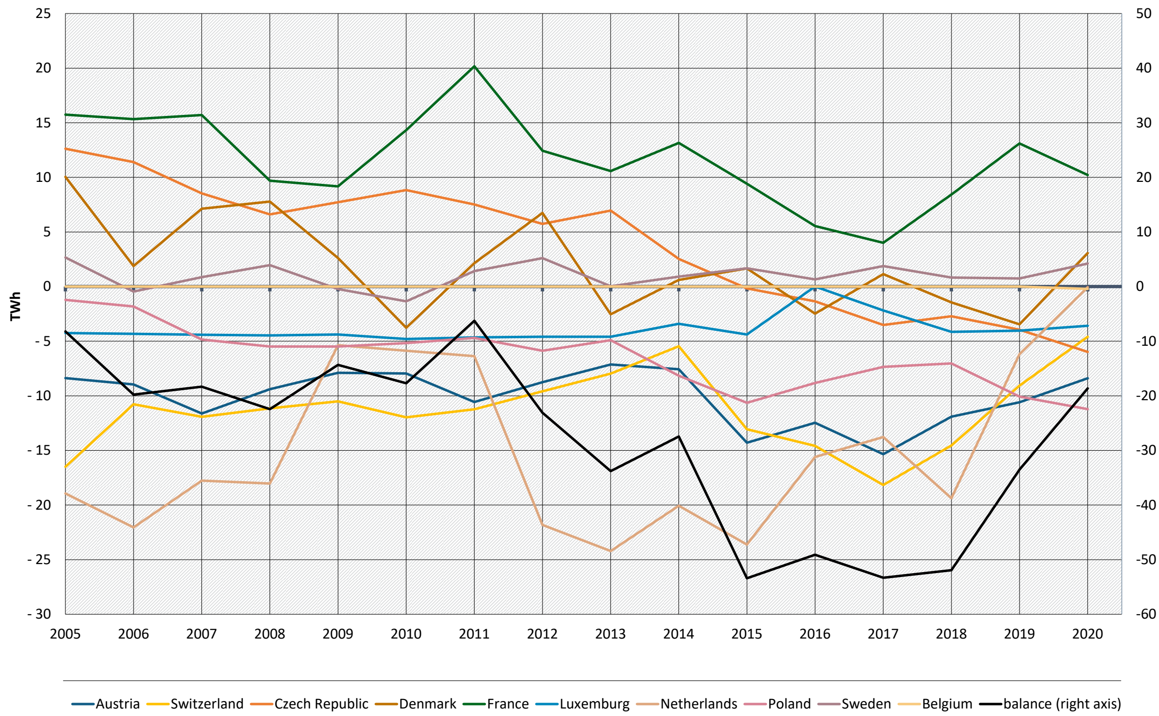


Source: Ember (2020).

Figure 43 shows the physical net import and export flows of electricity between Germany and its neighbouring countries between 2005 and 2020. Germany has electric connections to ten countries: Austria, Switzerland, the Czech Republic, Denmark, France, Luxembourg, the Netherlands, Poland, Sweden and, most recently, Belgium and Norway.

Physical net exports took place in all years from Germany to Austria, Switzerland, Luxembourg, the Netherlands and Poland. Net imports came from France in all years considered. At least some of these imports can be regarded as transports via Germany to Switzerland and Italy, when the French interconnectors to those countries are limited (Oeko-Institut 2013).. The exchange between Germany and the Czech Republic switched from net imports up to 2014 to net exports from 2015 onwards. Germany imported more electricity from Denmark than it exported to that country in most years except in 2010, 2013, 2016, 2018 and 2019. The same is the case for Sweden: Germany imported low amounts of electricity except in 2006, 2009 and 2010. Small net exports to Belgium can be observed in 2020.

Figure 43: Germany: Net import (positive) and net export (negative) of electricity, physical exchange with neighbouring countries



Source: ENTSO-E 2005-2015; Bundesnetzagentur | SMARD.de 2016-2020

6.5 Market setting

6.5.1 Regional market allocation and interconnectors

The designated NEMO (Nominated Electricity Market Operator) in Germany is Nord Pool EMCO AS. Other active NEMOs are EPEX Spot SE, EXAA AG and Nasdaq Oslo ASA (ACER 2022). The highest liquidity is reported for EPEX Spot (trades at the day ahead market of 198 TWh at EPEX Spot vs. 18 TWh at Nord Pool in 2020) (BNetzA; BKartA 2022).

Since the liberalisation of the European electricity markets in 2002, Germany, Austria and Luxembourg has formed a common price zone. After the Tri-Lateral Market Coupling (TLC) integrated the French, Belgian and Dutch Day-Ahead markets from 2006 onwards, Germany, Austria and Luxembourg joined in 2010 and thereby formed the market coupling in Central West Europe called CWE (Epex Spot). Following further extensions of the market coupling, Germany is now part of the Multi-Regional Coupling (MRC). However, the joint price zone with Austria was terminated in 2018 following a decision by the Agency for the Cooperation of Energy Regulators (ACER) to avoid loop flows in neighbouring Eastern European grids caused by too high exports to Austria at certain times and to reduce the re-dispatch of power plants

CLEW 2015. The transfer capacity between Austria and Germany is defined with at least 4900 MW (Bundesnetzagentur | SMARD.de 2018).

Table 23 shows the maximum forecasted transfer capacities between Germany and its neighbours according to ENTSO-E data. The transmission capacity to Poland is determined by the German and Czech TSO based on the NTC capacity calculation method. The latter uses the combination of the transmission capacities between Germany and Poland as well as Germany and the Czech Republic to calculate the available transmission capacities (50Hertz; Amprion; TenneT; TransnetBW 2021).

Table 23: Germany: Maximum transfer capacity with neighbouring countries in 2020 (MW)

		BE	DK	CH	NL	FR	SE	CZ	PL/CZ
DE	to	572	2181	1264	3016	5820	322	1050	1042
DE	from	572	1901	3708	3561	4810	516	1421	1415

Source: BNetzA; BKartA 2022.

6.5.2 Electricity market design with reference to conventional power generation plants

There is no capacity market in Germany. Instead, there are various regulations for power plants that serve in some form as reserve capacities. The “capacity reserve” comprises gas-fired power plants with a total capacity of 1 GW. They are selected through auctions by the Federal Network Agency and are not allowed to operate on the regular electricity market. The so-called “security stand-by” was introduced in 2016 to remove lignite-fired power plants with a capacity of 2.7 GW from the electricity market and to link this step with remuneration. Following the nuclear phase-out decision, the 2016 Electricity Market Act created the possibility of constructing “special grid-related equipment” with a capacity of up to 2 GW. As a result, four new power plants with a total capacity of 1.2 GW are under construction that are to serve as reserve capacity only. In addition to the three types of reserve mentioned so far, which serve to compensate for insufficient capacity, the grid reserve ensures that power plants are available for re-dispatch to prevent local grid overloads. The grid reserve contains power plants with a total capacity of 5.7 GW.

Another instrument from which conventional power plants benefit is the Combined Heat and Power Act (CHP Act) which has been the main basis for the promotion of CHP plants since 2002. Efficient combined heat and power generation gets funding in the form of a supplement for a limited period based on the application of a surcharge on the electricity produced in combined heat-and-power mode.

7 Italy

7.1 Key messages

- In 2019, combustion installations (Activity Code 20) in Italy emitted 83 Mt CO_2, which made Italy the 3rd largest emitter (9 %) in this category. Electricity producers account for 87 % of emissions under this category. Between 2013 and 2019, emissions from electricity generators decreased by 21 %.
- The generation mix is dominated by gas-fired generation, which accounts for about 50 % of gross electricity production in 2019. Hard coal contributed a share of 6 % in 2019, while in 2013 generation amounted to 45 TWh or 60 % higher. Only one third of the coal-fired generation fleet was installed before 1990. The share of other fossil fuels (such as waste gases from refineries and steelmaking) has strongly declined since 2005 and comprised only 5 % in total generation in 2019.
- The emission factor of gross electricity production of 0.25 t CO_2 per MWh is at a similar level as the value for the EU-28. With decreasing generation by coal and other fossil fuels, it has decreased by more than 20 % since 2013.
- Electricity supply from renewables comprised 40 % of total generation in 2019. Hydro power is a traditional renewable energy source in Italy, generating 40 to 60 TWh and contributing 40 % of the renewable electricity share in 2019. Biomass, wind and solar were expanded rapidly in the period until 2014, then stagnated up to 2018, and installations increased again only in 2019.
- Italy is a major importer of electricity in the Central European electricity system, with 43 TWh of imports on average between 2005 and 2019. Correspondingly, electricity prices set by gas-fired generation and imports are high compared to nuclear or coal-based generation in France or Germany, the main exporters of electricity to Italy (with Germany also supplying via Switzerland and Austria).
- A coal phase-out planned for 2025 is linked to the construction of new gas-fired capacities, which are planned to be procured through auctions. Due to delays in the expansion of Sardinia's connection to the mainland, the coal-fired power plant there will continue to operate until 2027.

Table 24 Italy: Key figures on the electricity sector in 2019

	2019	% change compared to 2013
	CO_2 emissions	
Total CO_2 emissions in 2019 from ETS Activity Code 20 (share of EU-28)	83 Mt CO_2 (9%)	-18%
Total CO_2 emissions from electricity producers[1] (share of combustion installations in the country)	72 Mt CO_2 (87%)	-21%
Emission factor of gross electricity production[2] (relative to EU-28 average)	0.25 t CO_2/MWh (105%)	-21%
	Gross electricity generation	
Total (share of total EU-28)	289 TWh (9%)	0%
Net electricity imports	41 TWh	-4%
Lignite share in gross generation (share of total gross lignite-fired generation in EU-28)	0% (0%)	0%
Hard coal share in gross generation (share of total gross hard coal-fired generation in EU-28)	6% (8%)	-59%
RES share in gross generation (target for 2030)[3]	40% (55%)	2%
	Installed capacity	
Total lignite-fired capacity installed (share of total EU-28)	0 GW (0%)	0%
Share of lignite-fired capacity installed before 1990 (share of total EU-28)	0%	0%
Total hard coal-fired capacity installed (share of total EU-28)	8.6 GW (9%)	-11%
Share of hard coal-fired capacity installed before 1990 (share of total EU-28)	34% (6%)	-19%

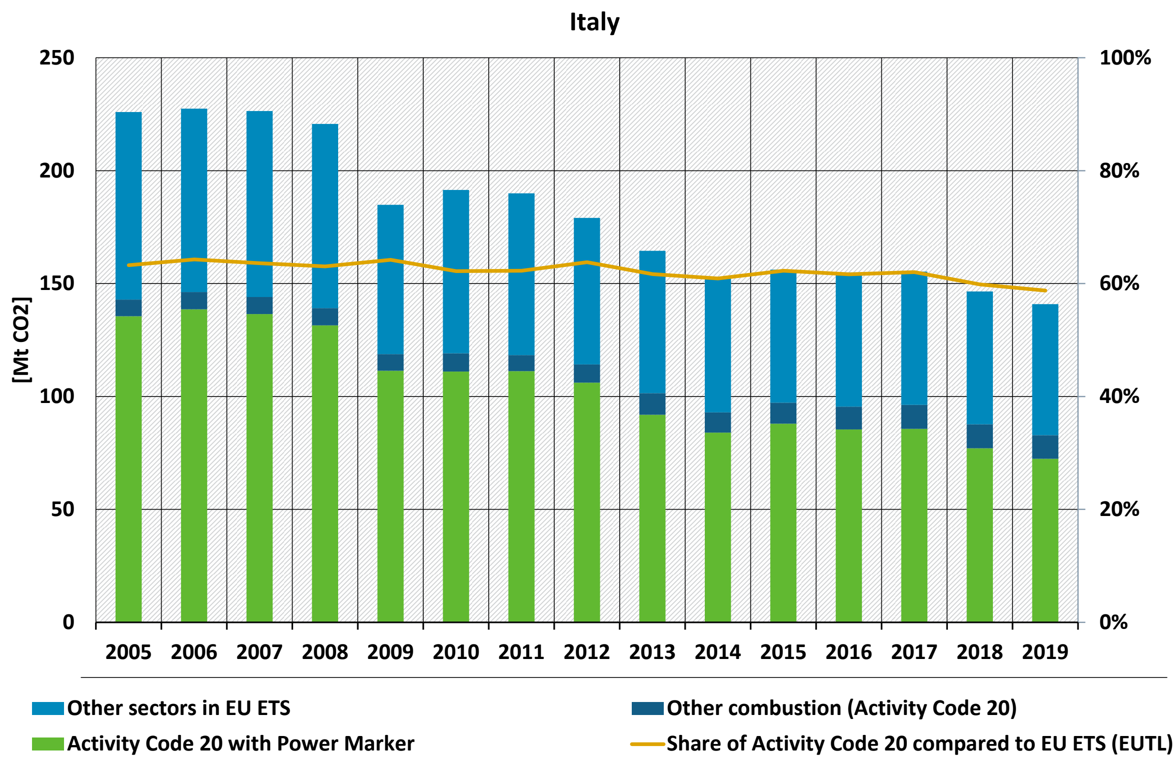
Note: [1] CO_2 emissions from electricity producers based on power plants identified in Oeko-Institut's EU ETS database.
[2] Emission factor calculated based on CO_2 emissions by power plants identified in Oeko-Institut's EU ETS database and gross electricity production reported by Ember (2020).
[3] According to Article 4 (2) Regulation (EU) 2018/1999, MSs have to provide information on their contribution to the Union's binding renewable energy target of at least 32% expressed as renewable energy share on gross final energy consumption. They do so in their NECPs (Article 3(2)(b)). Along with this contribution they also have to report on *estimated trajectories for the sectoral share of renewable energy in final energy consumption from 2021 to 2030 in the electricity, heating and cooling, and transport sector* (see Annex I Regulation (EU) 2018/1999 which sets out the structure of the NECPs)
Source: Own table based on Ember (2020), EC n.d., Europe Beyond Coal (2022), and EEA (2021).

7.2 Emission trends in the EU ETS (combustion installations)

Figure 44 shows CO_2 emissions from the EU ETS in Italy from 2005 to 2019. CO_2 emissions from Activity Code 20 in the EUTL (combustions installations) constitute a share of about 60 % of those, with a slightly declining trend from 63 % in 2005 to 59 % in 2019. Overall EU ETS emissions dropped from more than 225 Mt CO_2 in the period between 2005 and 2008 to 150 Mt CO_2 in 2019. Emissions from Activity Code 20 and from other EU ETS sectors decreased more or less proportionally compared to overall EU ETS emissions in Italy.

As also shown in Figure 44, the electricity sector (Activity Code 20 with Oeko-Institut's Power Marker) constantly makes up the largest share of emissions under Activity Code 20 with 95 % in 2005 and declining to 87 % in 2019.

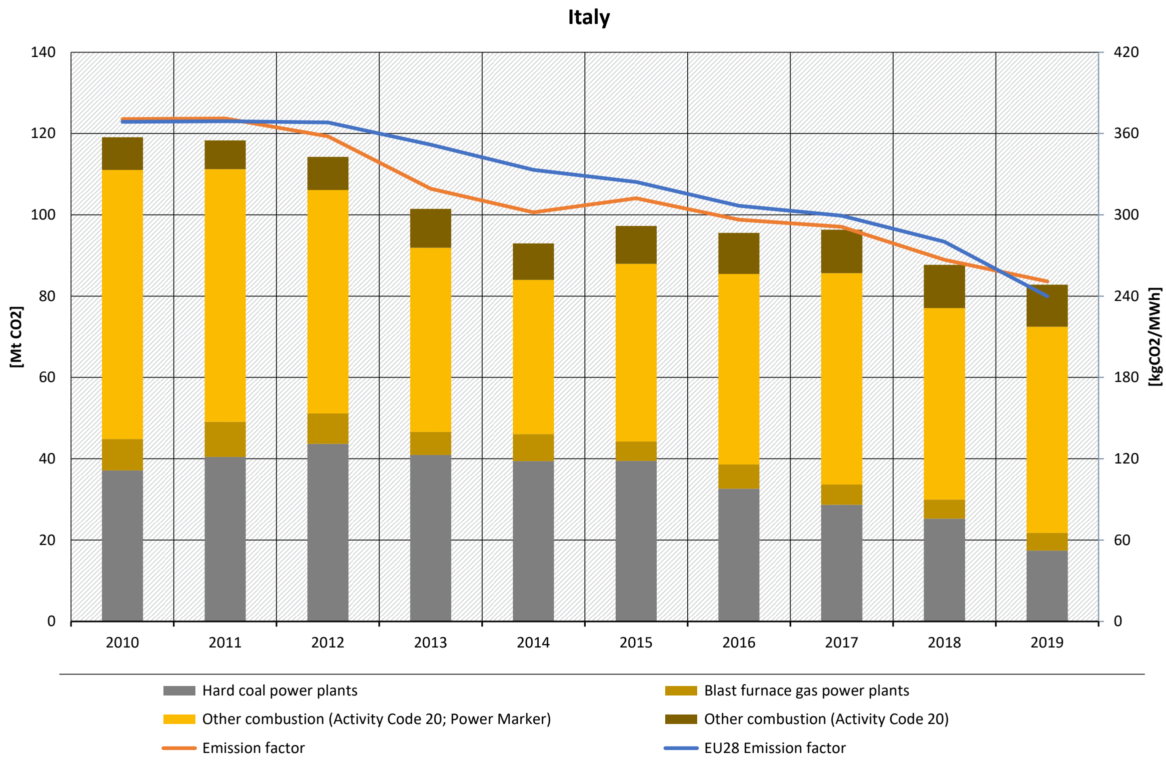
Figure 44: Italy: Emission trends in the EU ETS



Source: Own compilation of data based on EC n.d., and EEA (2021).

Figure 45 shows CO_2 emissions from Activity Code 20 disaggregated by fuel from 2010 onwards. Emissions from hard coal power plants roughly halved from a level of about 40 Mt CO_2 in the years 2005 to 2015 to less than 20 Mt CO_2 in 2019. Emissions from other fossil-fuelled power plants (mainly natural gas) decreased from 66 Mt in 2010 to 38 Mt CO_2 in 2014, increased up to 2017 and remained at approx. 50 Mt CO_2 in the subsequent years. Italy also has CO_2 emissions from blast furnace gas, which fell from 8 Mt CO_2 in 2010 to 4 Mt CO_2 in 2019. Emissions from other combustion installations without the Power Marker vary between 7 and 11 Mt CO_2 in the years considered.

Figure 45: Italy: Emission trends in Activity Code 20



Note: Emissions in the category: other combustion (Activity Code 20; Power Marker) are calculated using the deduction method: All emissions with Power Marker minus emissions from hard coal-fired power plants minus emissions from blast furnace gas power plants.
Source: Own illustration based on data from Europe Beyond Coal (2022), EEA (2021), Ember (2020),and own assignment based on EC n.d..

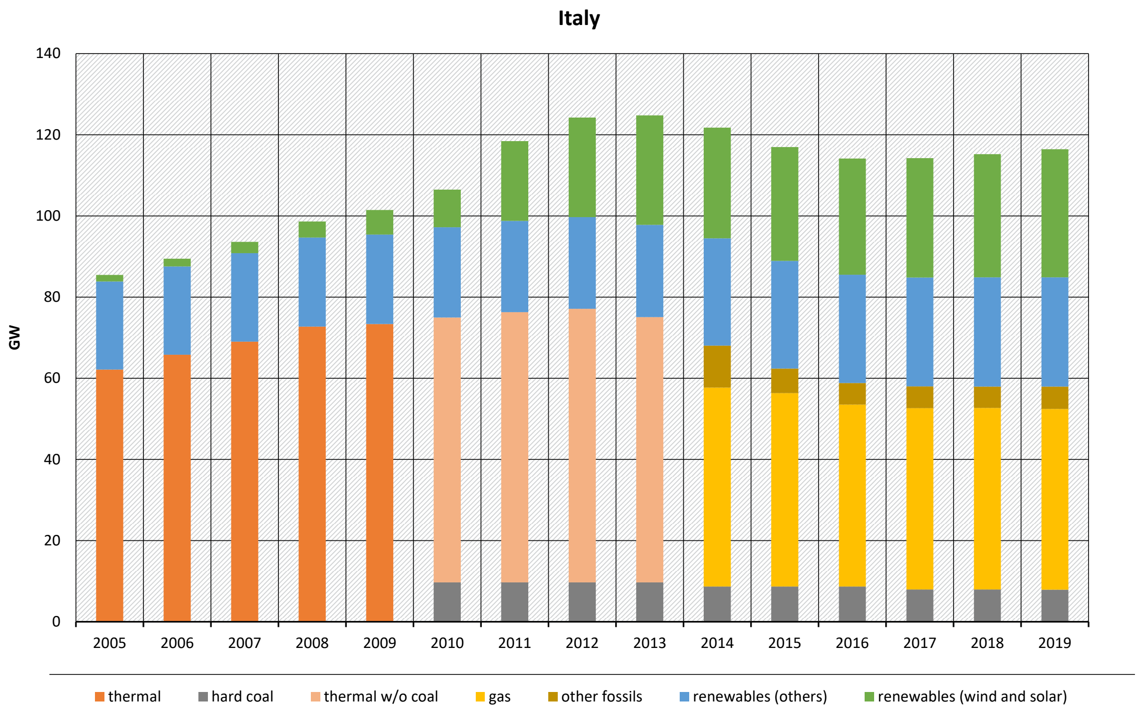
The emission factor of Italy's combustion plants decreased from 370 kg CO_2/MWh in 2010 to 250 kg CO_2/MWh in 2019. Compared to the average EU-28 emission factor, Italy's emission factor has a very similar level but was slightly lower between 2012 and 2018. In 2013 and 2014, the Italian development led to a larger downward deviation, but due to the decrease in the EU emission factor, the values converged again in recent years. In 2019, the average EU-28 emission factor has dropped slightly below the Italian emission factor.

7.3 Capacity trends

7.3.1 Existing capacities

Figure 46 shows the development of the installed capacity of Italian power plants from 2005 to 2019. Thermal power plants (including biomass) are shown in aggregate due to a lack of data up to 2009. Data for the capacity of hard coal-fired power plants are available from 2010 onwards. From 2014, natural gas and other fossil power plants are also included individually. Biomass is included in other renewables as of 2014.

Figure 46: Italy: Evolution of capacity trends by energy carrier

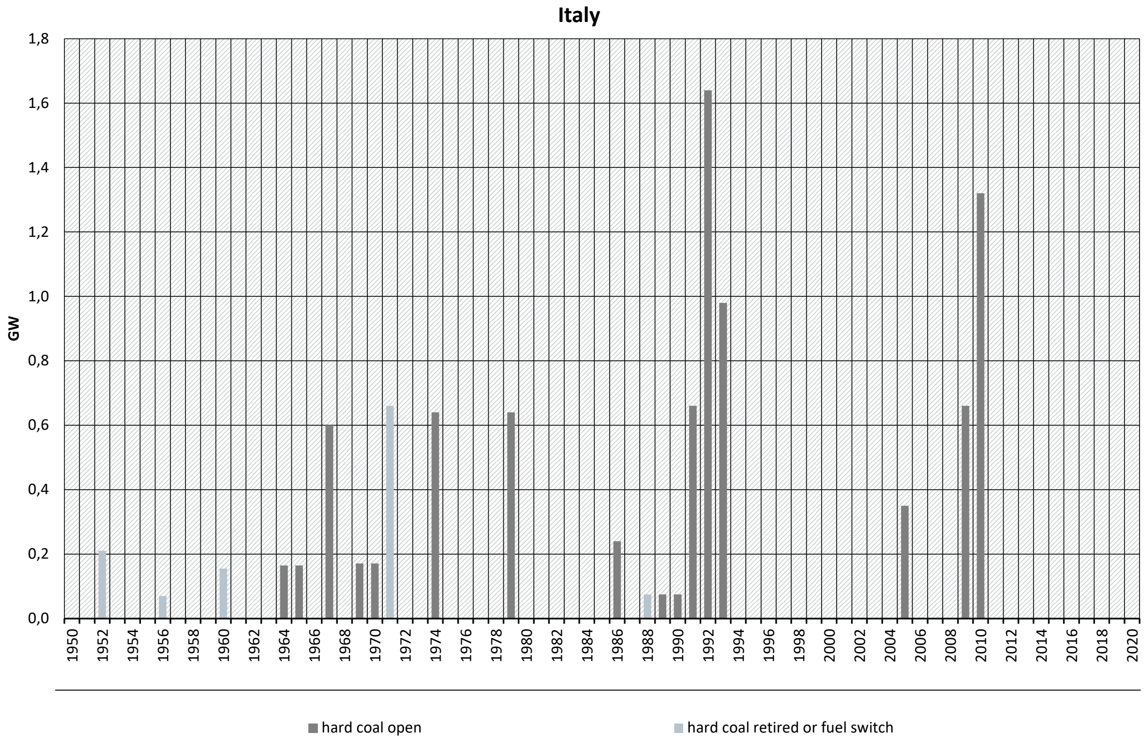


Note: Capacities with the energy carrier biomass are included in thermal and thermal w/o coal until 2013 and in renewables (others) from 2014.
Source: Own illustration based on data from Terna (2005-2019), Europe Beyond Coal (2022).

The installed capacity of thermal power plants rose from just over 60 GW to 77 GW between 2005 and 2012. Since 2013, their capacity has fallen again, and remained constant at just under 60 GW (now excluding about 3.5 GW biomass) between 2016 and 2019. The major share of Italian power plants is fuelled by natural gas; from 2014 to 2019, this share decreased slightly from 49 GW to 44 GW. Hard coal power plant capacity dropped from 10 to 8 GW from 2010 to 2019. The other fossils category mainly consists of power plants fuelled by oil products. Their capacity decreased from about 7 GW to 2 GW. There is a traditionally high share of hydroelectric power plants in the Italian system. Steadily remaining at around 22 GW, they account for the largest share of other renewable energies. The installed capacity of wind and solar increased over the period considered: from less than 2 GW in 2005 to 32 GW in 2019, including 11 GW of wind and 21 GW of solar. Italy phased out nuclear power in 1990 as a result of a referendum in 1987 following the reactor disaster in Chernobyl.

A comparison of Figure 45 and Figure 46 shows that although hard coal power plants account for only a small share of installed capacity, they are responsible for a significantly larger share of power plant emissions. Figure 47 therefore takes a closer look at the Italian hard coal power plants by detailing their age structure. The graph includes coal plants that have since been retired in a paler shade. Two more intensive investment phases can be identified: from 1986 to 1993, a total of 3.7 GW was added, and another 2.3 GW followed from 2005 to 2010.

Figure 47: Italy: Age structure of hard coal power plants sorted by year of commissioning



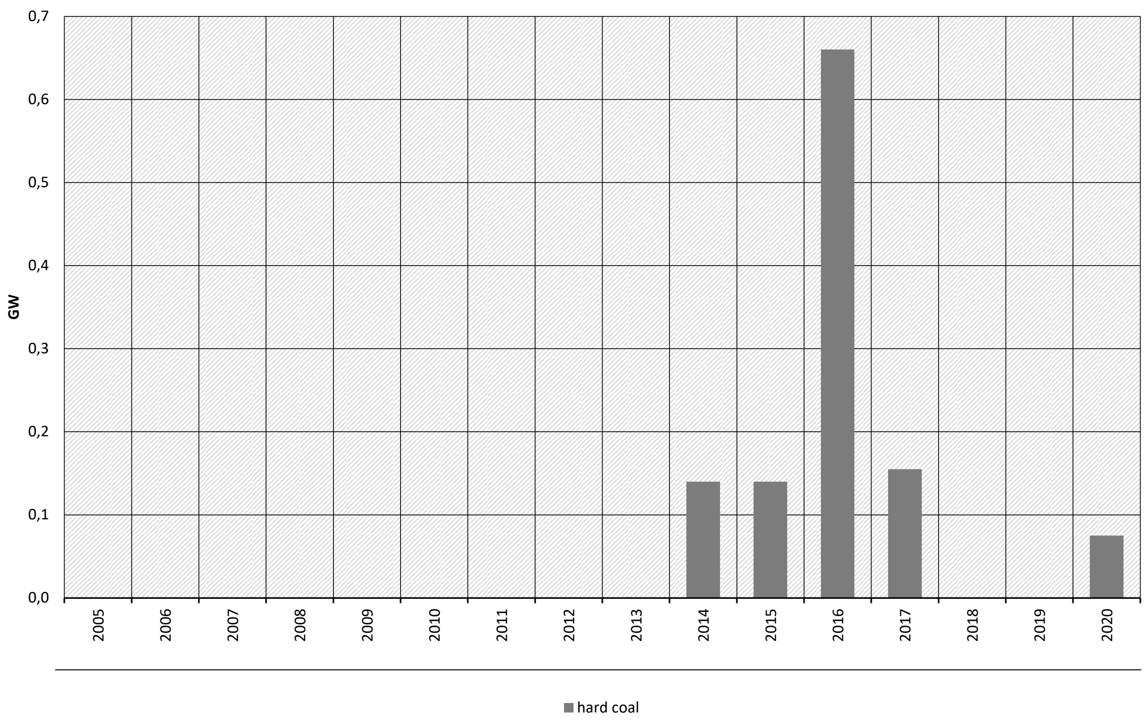
Source: Own illustration based on data from Europe Beyond Coal (2022).

There are currently 8 hard coal power plant sites. The three newest 660 MW blocks (from 2009 and 2010) are located at Torrevaldaliga nord power plant in the Lazio region. The next modern block from 2005 is a 350 MW block at Sulcis power plant in Sardinia.

The last investments prior to that were realised at Brindisi Sud power plant in the Puglia region, which consists of 4 blocks with 660 MW each commissioned between 1991 and 1993.

Figure 48 shows the retired coal-fired plants in Italy since 2005. Eight hard coal units with a total capacity of 1.2 GW were decommissioned between 2014 and 2020. Five of these units were small blocks with a capacity of about 70 MW each; the other three blocks had a capacity between 150 and 330 MW each.

Figure 48: Italy: Retired coal-fired plant capacities sorted by retirement date



Source: Own illustration based on data from Europe Beyond Coal (2022).

7.3.2 Future capacity trends

Conventional power plants

Despite the above-mentioned recent investments (see 7.3.1), Italy decided to shut down all coal-fired power plants by 2025 in order to reach its climate targets as stated in Italy's NECP (Ministry of Economic Development, Ministry of the Environment and Protection of Natural Resources and the Sea, Ministry of Infrastructure and Transport 2019). Due to delays in the expansion of Sardinia's connection to the mainland, the coal-fired power plant there will continue to operate until 2027 (Enel 2023, pp. 10–21).

The Italian plan to phase out hard coal also calls for the construction of additional gas-fueled power plants, as also described in the NECP: Between 2020 and 2025, new gas power plants of about 3 GW are planned. The two first tender procedures for new gas power plants with delivery in 2022 and 2023 were held in 2019.

Mining areas

The only coal resources in Italy are found in Sardinia. Mining there ceased in 1972. It resumed in 1997 and was closed again in 2018. Since then, Italy has imported all its coal (Euracoal 2020).

Targets for power generation based on renewable energies

Italy's target for renewable energies in the electricity sector is a share of 55 % of gross final electricity consumption in 2030. According to the NECP, this corresponds to 187 TWh. This target is mainly based on the expansion of photovoltaic and wind energy.

Italy has a variety of support schemes for renewable energies in the electricity sector (and had more in the past) depending on the technology, size of the plant and the year of construction.

The basic mechanism is mostly either a feed-in tariff or a feed-in-premium as well as a supported form of self-consumption. Tax reductions are also part of the support schemes. Additional measures were taken with the FER 1 Decree in 2019, which provides incentives for the construction of about 8 GW renewable energy capacity based on solar, onshore wind, hydroelectric and sewage gases. The scheme is limited to the end of 2021 and is based on seven auction rounds in which successful projects receive a feed-in premium on the zonal hourly market prices. For projects larger than 1 MW the auction pools all technologies. Projects below 1 MW are selected based on environmental and economic priority criteria. The premium for these plants is limited to the difference between the applicable tariff for each renewable technology and the zonal hourly market prices (Dentons 2020b).

7.3.3 Ownership structure of coal power plants

Table 25 shows the ownership structure of the coal fired power plants in Italy. The biggest share (81 %) summing up to almost 7 GW is owned by Enel. Two more blocks belong to A2A and EPH respectively.

Table 25: Italy: Ownership structure of the coal-fired electricity generation fleet

	Gross generation capacity [MW]	Company's share of total coal capacity	
Owner	hard coal	share %	cum. share %
Enel	6936	81%	81%
A2A	976	11%	93%
EPH	640	7%	100%

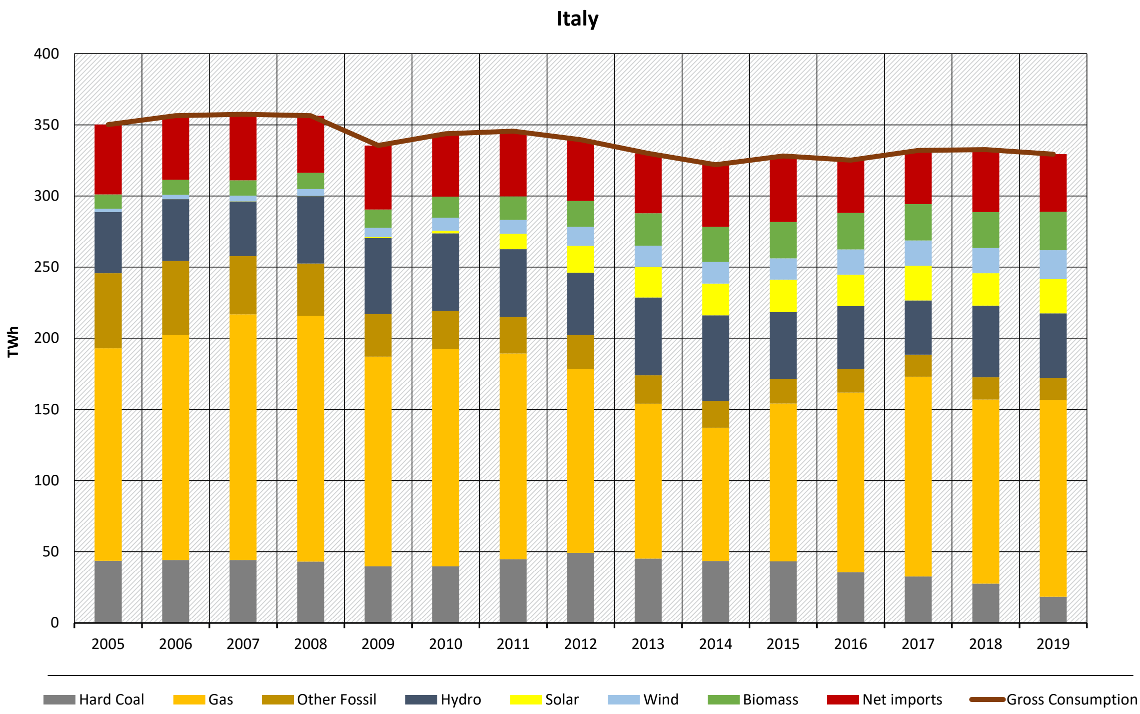
Source: Own table based on Europe Beyond Coal (2022).

7.4 Trends in electricity generation and import balance

Figure 49 shows gross electricity generation including imports to Italy between 2005 and 2019, broken down by fuel, as well as gross consumption.

Gross consumption has slightly decreased from about 350 TWh between 2005 and 2008 to values of approx. 330 TWh in recent years. A minimum of demand was registered in 2014 with approx. 320 TWh. According to market observers this was due to the economic stagnation as well as a low heating and cooling consumption because of mild weather (Rossetto 2015).

Figure 49: Italy: Trends of gross electricity generation and net imports

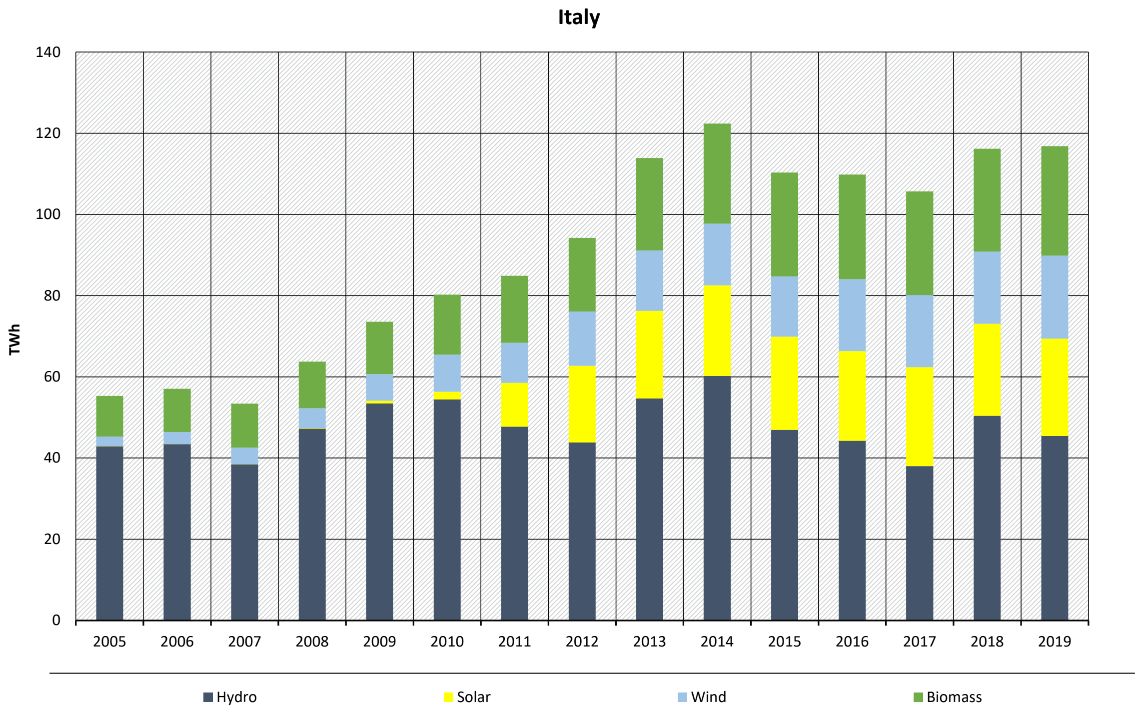


Source: Ember (2020).

Gas is the major energy carrier in the Italian electricity system. It provided between 94 TWh and 173 TWh in the period considered. This comprises 34 % to 56 % of domestic gross production, depending on the year, and 29 % to 48 % of gross consumption. The role of hard coal has diminished in recent years; the contribution of hard coal has more than halved between 2005 and 2019, from 43 TWh to 18 TWh. Electricity generation from other fossils also decreased; this was mainly due to the decline of the use of petroleum products.

Renewable electricity generation in Italy is traditionally strong in hydro power, as can be seen in Figure 50. It has provided between 40 and 60 TWh in the years since 2005. There is also a contribution of approx. 10 TWh of electricity from biomass that was already in place in 2005 and the subsequent years. A major expansion of renewable electricity generation can be observed from about 2009 onwards: wind, photovoltaics and also biomass increased their shares in the subsequent years but reached a roughly constant level by 2015. In 2019, biomass is the second largest renewable source of electricity with 27 TWh; solar is third with 24 TWh; and wind is number four with 20 TWh.

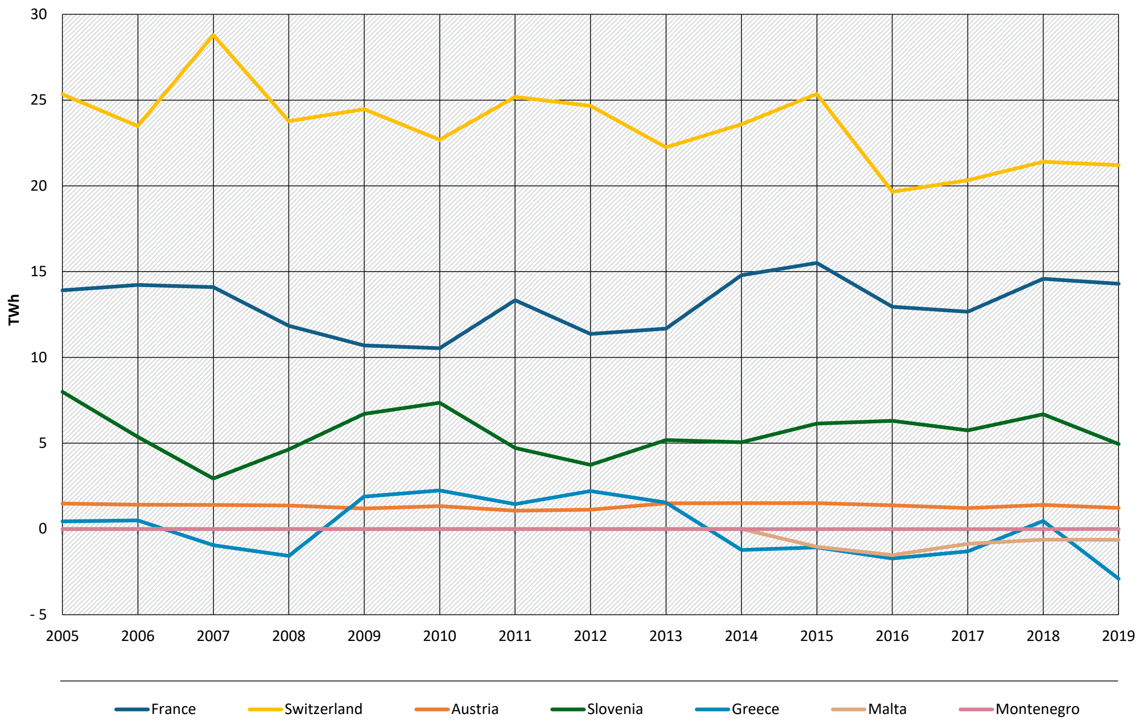
Figure 50: Italy: Electricity generation of renewable energies



Source: Ember (2020).

Figure 49 also shows the net imports of electricity to Italy. Yearly net imports vary between 37 and 49 TWh in the period considered. Italy is connected to Switzerland, France, Austria, Slovenia, Greece, Malta and recently also to Montenegro. As detailed in Figure 51, the largest shares of net imports reach Italy from Switzerland, France and Slovenia. Net imports from Switzerland decreased from levels of 25 to 29 TWh in the years 2005 to 2007 to around 20 TWh in recent years. Net imports from France range between about 10 and 15 TWh with a slightly increasing tendency. Net imports from Slovenia fluctuated between 3 and 8 TWh per year. On balance, approx. one TWh per year flows from Austria to Italy. To a large extent, imports from Switzerland can be attributed to transits from France, and Germany, and similarly, imports from Austria can be attributed to transits from Germany. The electricity exchange with Greece varies between net imports and net exports. Since 2015, there have also been low net electricity exports to Malta and since 2019 a very low electricity exchange with Montenegro.

Figure 51: Italy: Net import (positive) and net export (negative) of electricity, physical exchange with neighbouring countries



Source: Terna 2006-2019.

7.5 Market setting

7.5.1 Regional market allocation and interconnectors

The NEMO (Nominated Electricity Market Operator) in Italy is Gestore dei Mercati Energetici S.p.A (GME). GME manages the spot market, which consists of a day-ahead market and the intraday market, and the forward electricity market. The Italian spot market is organised into market zones, grouping network nodes into bidding zones, the division of which has changed over recent years. Since January 2021, there have been seven market zones: North, Centre-North, Centre-South, South, Calabria, Sicily and Sardinia (lightbox 2021). At the day-ahead market, producers see a zonal price while for consumers the cost is levelled with a single national price. At the intraday market, both bids for sale and bids to buy are valued at the zonal price (Ministry of Economic Development, Ministry of the Environment and Protection of Natural Resources and the Sea, Ministry of Infrastructure and Transport 2019).

Italy has been part of the Multi Regional Coupling (MRC) since February 2015, when it was launched on the northern border with France, Austria and Slovenia.

Today the zones of the Italian market are interconnected with neighbouring countries: the North with France, Switzerland, Austria and Slovenia; the Centre-North and Sardinia with Corsica; the Centre-South with Montenegro; the South with Greece, Sicily with Malta. Table 26 summarizes forecasted maximum transfer capacity with neighbouring countries in 2021.

Table 26: Italy: Maximum forecasted transfer capacity with neighbouring countries in 2021 (MW)

		CH	SI	FR	GR	AT	ME
IT	to	1810	660	995	50	100	600
IT	from	3213	537	1818	50	256	600

Source: Own data based on ENTSO-E.

7.5.2 Electricity market design with reference to conventional power generation plants

Italy introduced a capacity market in 2019. It is an auction-based mechanism organized by Terna as a central buyer. The calculation of required amounts is based on a yearly updated long-term system adequacy assessment by Terna. The mechanism is open to different technologies including power plants, storage, renewable energies and demand-side response including foreign resources. Thermal power plants have to comply with binding CO_2 emission limits of 550 g CO_2/kWh according to the European Regulation 2019/943 on the Internal Market for Electricity (Article 22(4)) (Europäisches Parlament und Europäischer Rat 2019), which excludes coal-based power plants from any capacity payments.

The NECP (Ministry of Economic Development, Ministry of the Environment and Protection of Natural Resources and the Sea, Ministry of Infrastructure and Transport 2019) provides a detailed account of the first two action rounds: "At the first auction, held on 6 November 2019 for delivery year 2022, the TSO assigned over 40 GW of capacity broken down as follows: 34.7 GW existing capacity (of which 1 GW from RES), 1.7 GW of new power plants and 4.4 GW of virtual capacity from abroad. At the second auction, held on 28 November 2019 for delivery year 2023, the TSO assigned around 43.4 GW of capacity with an increase largely due to new plants of 4 GW, whereas overall existing capacity (35 GW of which 1.3 GW from RES) as well as virtual capacity from abroad (4.4 GW) were confirmed. In both rounds the annual premiums for capacity assigned were 33.000 €/MW for existing plants, 75.000 €/MW for new plants and around 4.000 €/MW for virtual capacity from abroad, for a total of 1.3 billion Euro in the first allocation and almost 1.5 billion Euro in the second."

8 Netherlands

8.1 Key messages

- In 2019, combustion installations (Activity Code 20) in the Netherlands emitted 54 Mt CO_2, which made the Netherlands the 6th largest emitter (6 %) in this category. Electricity producers account for 74 % of emissions under this category. Between 2013 and 2019, emissions from electricity generators decreased by 11 % only (which is similar to the Czech Republic; electricity-related emissions fell more sharply in all other Member States analyzed).
- Due to domestic gas reserves, the generation mix is dominated by gas-fired generation, which accounted for approx. 50 to 60 % of gross electricity production between 2005 and 2019. Earthquakes followed by public protests led to the decision to reduce production at the Groningen Field in 2018; however, supply to domestic electricity producers was unaffected. On average, hard coal contributed a share of 24 % between 2005 and 2019. However, with the installation of three new blocks in 2015 and one in 2016 and a net capacity increase of 0.7 GW, the share increased to a peak of 36 % in 2015. The entire coal-fired generation fleet was installed after 1990. In the Netherlands, the co-firing of biomass in hard coal-fired power plants has been subsidized in the past and is still practised; however, it is no longer part of the support scheme for new plants. A small nuclear reactor provides a constant share of 3 to 4 % of gross production.
- The emission factor of gross electricity production of 0.33 t CO_2 per MWh is one third higher than the value for the EU-28 in 2019. While the levels were similar in 2010, the EU-28 emission factor decreased steadily while the Dutch emission factor increased with increasing coal-fired generation in the Netherlands in the years 2011 to 2013. Between 2013 and 2019, the Dutch emission factor decreased by 22 % only.
- Electricity supply from renewables comprised only 18 % of total generation in 2019. Wind and solar generation have expanded rapidly since 2013; biomass, the third largest RES-E source in the Netherlands, did not show a similar dynamic. Nevertheless, the Dutch NECP expects a 73 % share of renewables in electricity production by 2030. It is planned that this will come from strong additions in offshore wind, but also onshore wind and solar PV.
- The Netherlands is an important transit country for electricity from Germany and Norway to the UK. At the same time, the country was a net importer of electricity for most years in the period assessed. The extent of net imports was governed by excess generation from Germany.
- A coal phase-out plan targeting at the shutdown of the last plant by end of 2029 is in place. The Netherlands have also introduced a carbon floor price for electricity generation, starting at 12.30 Euro in 2020 and progressively increasing to 31.90 Euro by 2030.

Table 27 Netherlands: Key figures on the electricity sector in 2019

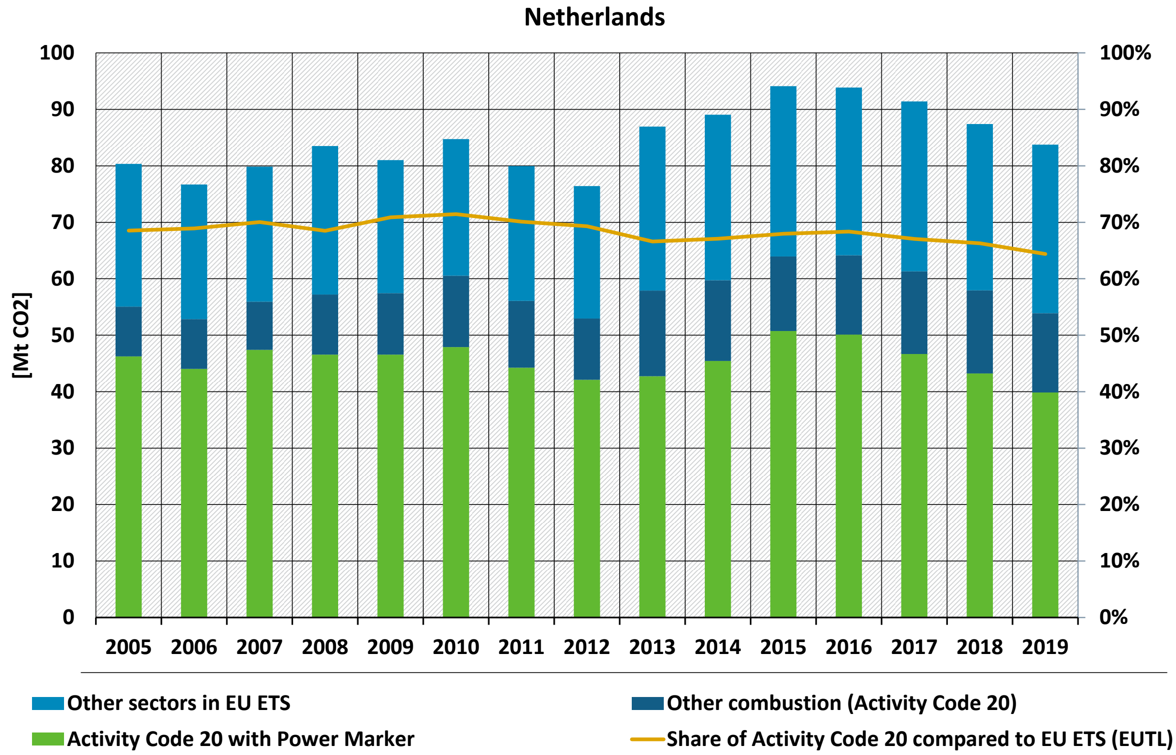
	2019	% change compared to 2013
	CO_2 emissions	
Total CO_2 emissions in 2019 from ETS Activity Code 20 (share of EU-28)	54 Mt CO_2 (6%)	-7%
Total CO_2 emissions from electricity producers[1] (share of combustion installations in the country)	40 Mt CO_2 (74%)	-7%
Emission factor of gross electricity production[2] (relative to EU-28 average)	0.33 t CO_2/MWh (138%)	-22%
	Gross electricity generation	
Total (share of total EU-28)	121 TWh (4%)	19%
Net electricity imports	0 TWh	-98%
Lignite share in gross generation (share of total gross lignite-fired generation in EU-28)	0% (0%)	0%
Hard coal share in gross generation (share of total gross hard coal-fired generation in EU-28)	14% (8%)	-33%
RES share in gross generation (target for 2030)[3]	18% (73%)	48%
	Installed capacity	
Total lignite-fired capacity installed (share of total EU-28)	0 GW (0%)	0%
Share of lignite-fired capacity installed before 1990 (share of total EU-28)	0%	0%
Total hard coal-fired capacity installed (share of total EU-28)	5 GW (5%)	16%
Share of hard coal-fired capacity installed before 1990 (share of total EU-28)	0% (0%)	-100%

Note: [1] CO_2 emissions from electricity producers based on power plants identified in Oeko-Institut's EU ETS database.
[2] Emission factor calculated based on CO_2 emissions by power plants identified in Oeko-Institut's EU ETS database and gross electricity production reported by Ember (2020).
[3] According to Article 4 (2) Regulation (EU) 2018/1999, MSs have to provide information on their contribution to the Union's binding renewable energy target of at least 32% expressed as renewable energy share on gross final energy consumption. They do so in their NECPs (Article 3(2)(b)). Along with this contribution they also have to report on *estimated trajectories for the sectoral share of renewable energy in final energy consumption from 2021 to 2030 in the electricity, heating and cooling, and transport sector* (see Annex I Regulation (EU) 2018/1999 which sets out the structure of the NECPs)
Source: Own table based on Ember (2020), EC n.d., Europe Beyond Coal (2022), and EEA (2021).

8.2 Emission trends in the EU ETS (combustion installations)

Figure 52 shows CO_2 emissions under the EU ETS in the Netherlands from 2005 to 2019. CO_2 emissions from combustion installations accounted for between 64 % and 71 % of total emissions. With no clear trend in the first years after the EU ETS was introduced, absolute emissions decreased up to 2012. They increased significantly in the subsequent years until 2015; since then, they continuously decreased again up to 2019.

Figure 52: Netherlands: Emission trends in the EU ETS

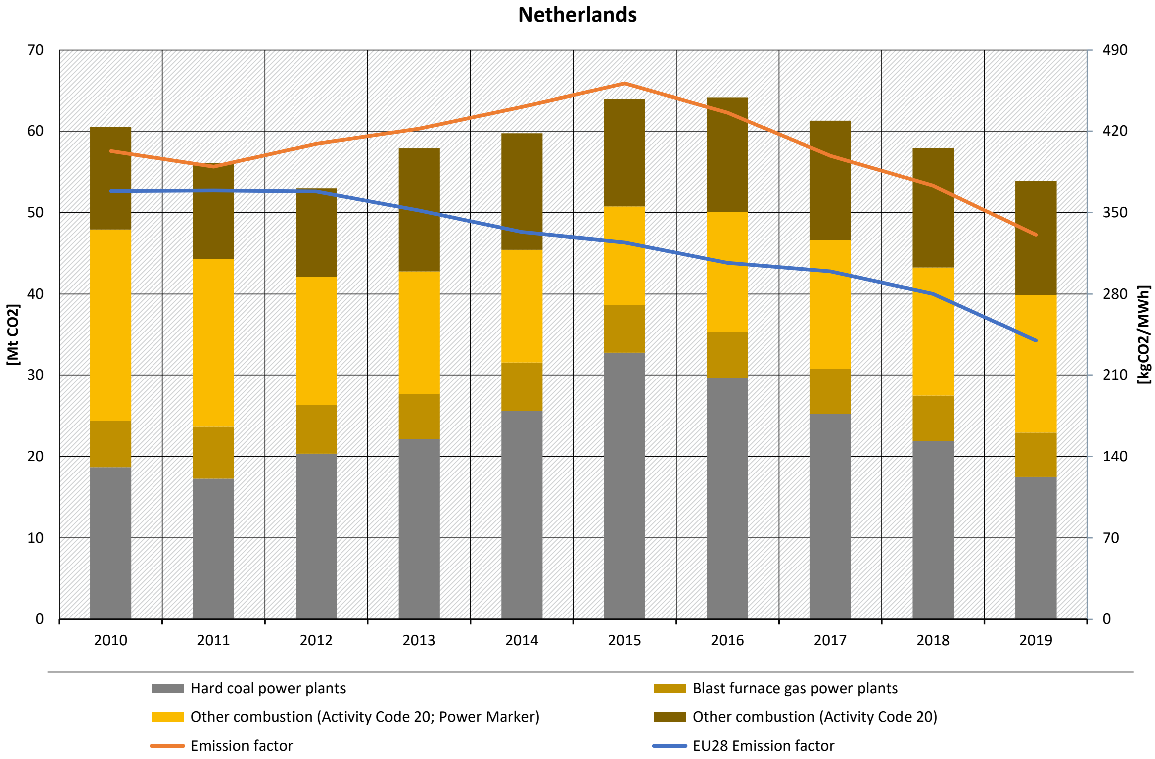


Source: Own compilation of data based on EC n.d., and EEA (2021).

The increase in emissions between 2012 and 2015 was caused not only by an increase in emissions from power generation, but also by emissions from other combustion installations and from other activities covered by the EU ETS. The increase in emissions from power generation was mainly caused by hard coal power plants (increase by more than 10 Mt CO_2 between 2013 and 2015, see Figure 53). Even though emissions from other power plants decreased during this period, the net effect was an increase in emissions from power generation. By 2019, the emissions from hard coal-fired generation had fallen back to 2010 levels, resulting in an overall decrease in combustion emissions.

As shown in Figure 53, the Dutch and the average EU-28 emission factors for power generation had a similar order of magnitude in 2010 and 2011. While the European emission factor decreased continuously during the period under consideration, the Dutch emission factor increased analogously to the described development of hard coal emissions up to 2015 and was still higher than the European emission factor by a factor of 1.3 in 2019 due to the comparatively slow uptake of renewable energy.

Figure 53: Netherlands: Emission trends in Activity Code 20



Note: Emissions in the category: other combustion (Activity Code 20; Power Marker) are calculated using the deduction method: All emissions with Power Marker minus emissions from lignite and hard coal-fired power plants minus emissions from blast furnace gas power plants.
Source: Own illustration based on data from Europe Beyond Coal (2022), EEA (2021), Ember (2020), and own classification based on EC n.d..

8.3 Capacity trends

8.3.1 Existing capacities

Figure 54 shows the installed capacities in the Netherlands between 2011 and 2018[7]. The Dutch power sector is dominated by **gas** power plants. Their installed capacity ranged between 17 and 21 GW in these years.

The installed capacity of **hard coal** power plants was 4.3 GW between 2011 and 2014. In 2015, three coal-fired blocks with a total capacity of 1.8 GW from the 1980s were retired and three new 870 MW blocks (total capacity 2.6 GW) started operation in the same year, with the result that capacity briefly rose to almost 7 GW in 2015. In addition, another 1.2 GW went into operation in 2016, resulting in a total hard coal capacity of 6.2 GW in 2016 and 2017. The further decommissioning of two 600 MW units left a capacity of 5.0 GW in 2018.

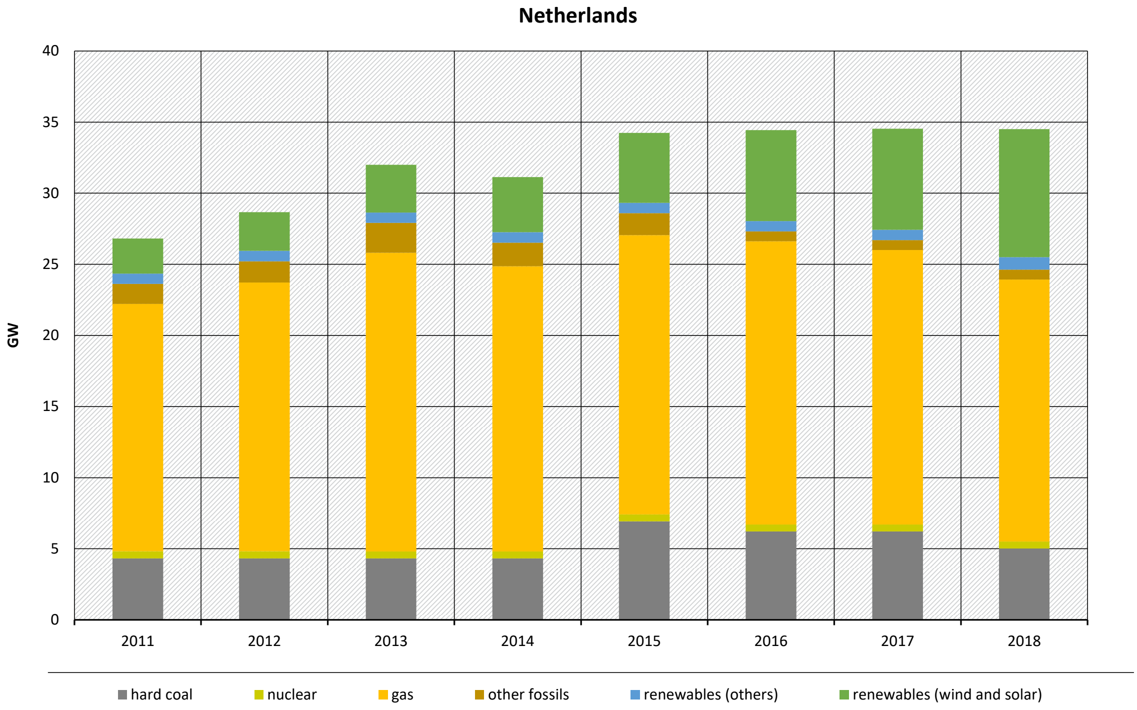
The Netherlands has one small **nuclear** power plant with 0.5 GW, the Borssele reactor which started operation in 1973.

Wind and solar are the largest renewable sources used in the Netherlands. The installed capacity of **wind onshore** turbines increased from 2 GW to about 3.5 GW between 2011 and 2018. **Wind offshore** capacities increased from 0.2 GW to just under 1 GW between 2011 and 2018.

[7] For 2019, the data for gas-fired power plant capacities are contradictory; therefore only the data up to 2018 are used.

Solar capacities grew quickly in the Netherlands from 0.15 GW in 2011 to 4.6 GW in 2018.

Figure 54: Netherlands: Evolution of capacity trends by energy carrier



Source: Own illustration based on data from Kendziorski et al. (2020), Europe Beyond Coal (2022), CBS Statline (2021).

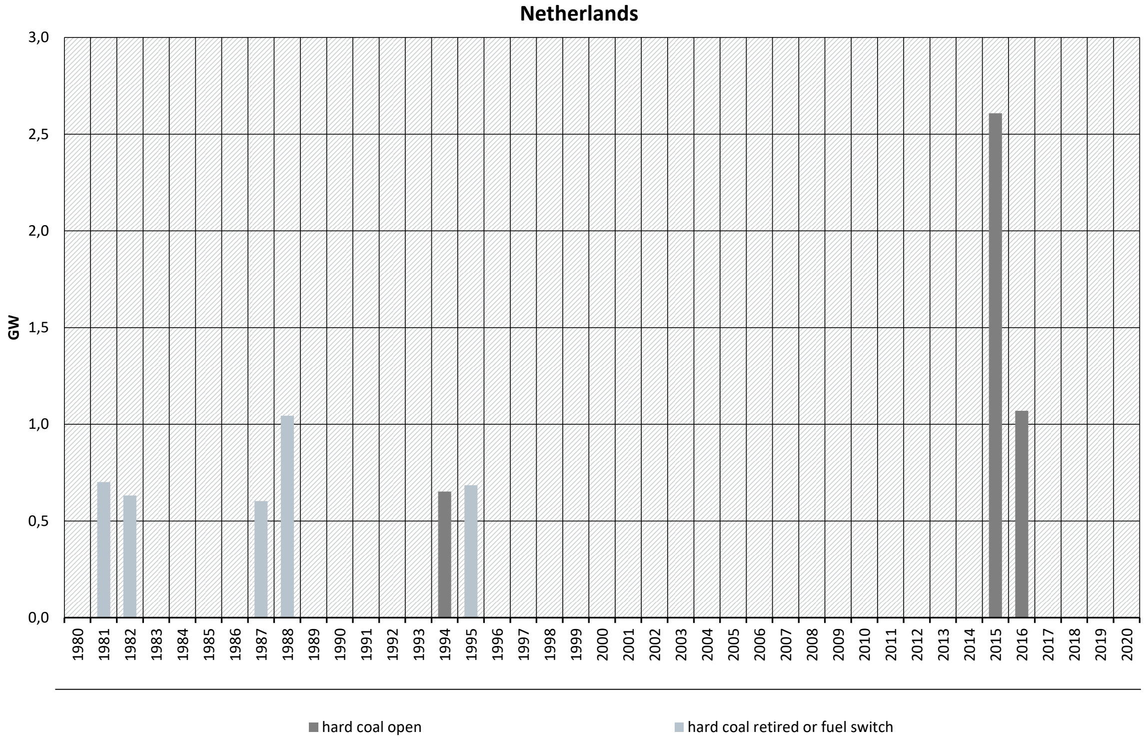
Figure 55 shows the age structure of coal-fired power plants in the Netherlands including those capacities in paler grey that are retired today or have undergone a fuel switch.

- The oldest hard coal blocks in the Netherlands recorded in the Europe Beyond Coal database date from the early 1980s. Three more blocks were commissioned in 1987/88. All hard coal blocks from the 1980s were retired in 2015 and 2017 (see also Figure 56).
- Two more hard coal power plants began operation in 1994 and 1995. One of them was retired in 2019, the other one (RWE's Amer 9 with 650 MW) is still operational but scheduled for retirement in 2024. It is fueled with 80 % biomass and 20 % coal (RWE).
- In 2015 and 2016, four new hard coal-fired power plants were commissioned. Those are three blocks with 870 MW each (Maasvlakte New, and two blocks at Eemshaven power plant) and one with 1100 MW (Maasvlakte 3). Riverstone/Onyx's 870 MW block (Maasvlakte New) had a technical failure in January 2020 and has not generated electricity since then (Ember 2021a). RWE's Eemshaven units 1 and 2 generate 15 % of the energy by biomass according to RWE (RWE). Uniper's Maasvlakte 3 power plant runs on up to 25 % biomass (Ember 2021b).

Without Maasvlakte New there a four operational hard coal power plants in the Netherlands.

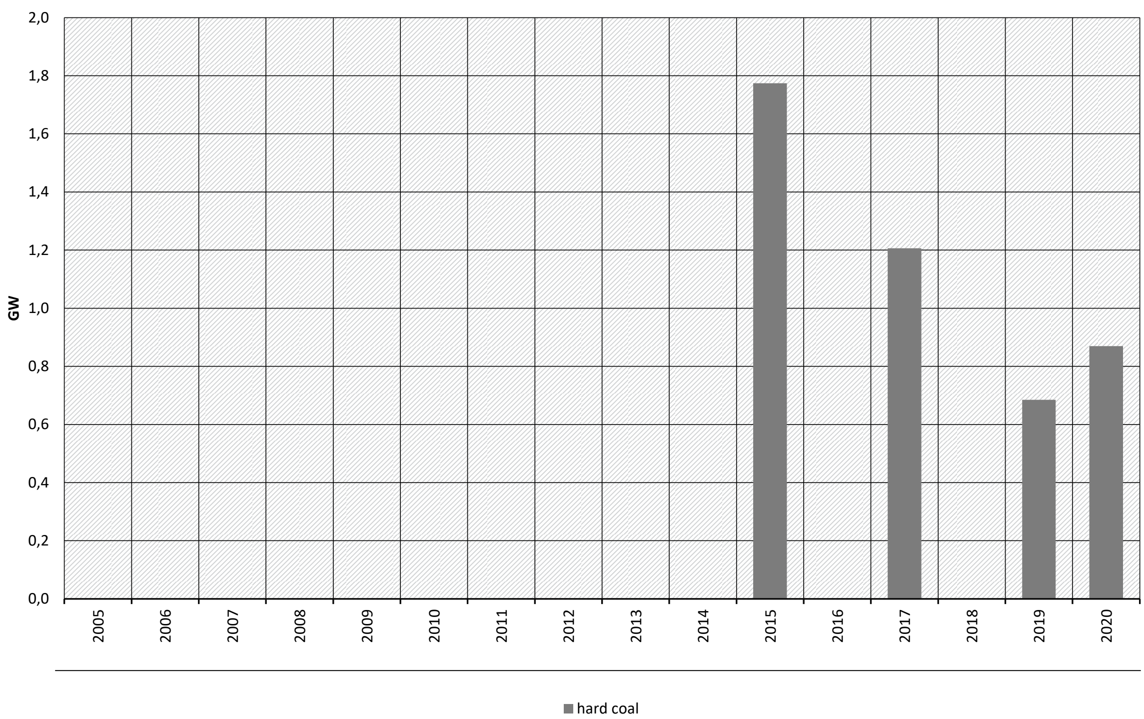
As Figure 56 shows, seven units with a total capacity of 4.5 GW were decommissioned between 2015 and 2020.

Figure 55: Netherlands: Age structure of hard coal power plants sorted by year of commissioning



Source: Own illustration based on data from Europe Beyond Coal (2022).

Figure 56: Netherlands: Retired coal-fired plant capacities sorted by retirement date



Source: Own illustration based on data from Europe Beyond Coal (2022).

8.3.2 Future capacity trends

Conventional power plants

The Dutch government decided to ban coal in the electricity sector by 2030. Power plants that have an efficiency of less than 44 % have to shut down by 2025 (Overheid.nl 2019). The Maasvlakte power plant owned by Riverstone/Onyx, which has not produced electricity since January 2020 due to technical problems, receives a subsidy in exchange for permanent closure of the power plant (RTL Nieuws 2020). This leaves four coal power plants that are subject to the law. The Amer 9 power plant by RWE is scheduled for retirement in 2024. The three remaining power plants, two from RWE (Eemshaven 1 and 2) and one from Uniper (Maasvlakte 3), must cease operation by end of 2029 at the latest.

The Dutch government states on its homepage that there are no plans for new nuclear power plants in the Netherlands (Government of the Netherlands). Nevertheless, the Dutch Ministry of Economic Affairs and Climate Policy is looking into options to build new nuclear plants in the future (World nuclear news 2021a).

Mining areas

The Netherlands imports all the coal it consumes. Coal mining has taken place in the Netherlands in the past. Dutch lignite mining ended in 1968; hard coal mining ended in 1974.

Targets for power generation based on renewable energies

The Dutch NECP (Ministry of Economic Affairs and Climate Policy 2019) of 2019 expects a 73 % share of renewables in electricity production by 2030. This is expected to be about 49 TWh from offshore wind, 35 TWh from onshore wind and solar, and about 10 TWh from small private plants, some of which are also solar panels. The latest Climate and Energy Report (KEV) 2021 (PBL 2021) of the Dutch Environmental Protection Agency (PBL), which already takes into account the new European targets of summer 2021, envisages a share of 75 % renewable electricity generation by 2030.

The main support scheme for electricity from renewable energy sources in the Netherlands is a premium tariff, whereby premiums are paid in addition to the wholesale price. The so-called SDE++ scheme ("Stimulation of Sustainable Energy Production and climate transition") has replaced the former SDE+ scheme ("Stimulation of Sustainable Energy Production") since 2020 and also includes greenhouse gas emission reduction technologies (Dentons 2020a). Another difference to the former SDE+ is that under the SDE++ scheme, the co-firing of biomass in coal-fired power plants is no longer eligible (EC 2020).

The previous support schemes were the MEP ("Environmental Quality of Power Production") from 2003 to 2006 and – after a period in 2007 when the feed-in tariffs were financed from the state budget – the SDE ("Stimulation of Sustainable Energy Production"), which was introduced in 2010 and replaced by the SDE+ scheme in 2010 (Xing Zhang 2020).

8.3.3 Ownership structure of coal power plants

Table 28 shows the ownership structure of the four operational coal fired power plants in the Netherlands. The three blocks that comprise the largest share (69 %) and total 2.4 GW are owned by RWE. One more block belongs to Uniper.

Table 28: Netherlands: Ownership structure of the coal-fired electricity generation fleet

	Gross generation capacity [MW]	Company's share of total coal capacity	
Owner	hard coal	share %	cum. Share %
RWE	2391	69%	69%
Uniper	1070	31%	100%

Source: Own table based on Europe Beyond Coal (2022).

8.4 Trends in electricity generation and import balance

Figure 57 shows gross electricity generation including imports to the Netherlands between 2005 and 2019, broken down by fuel, as well as gross consumption.

Gross consumption shows no clear trend in the period under consideration, fluctuating at around 120 TWh.

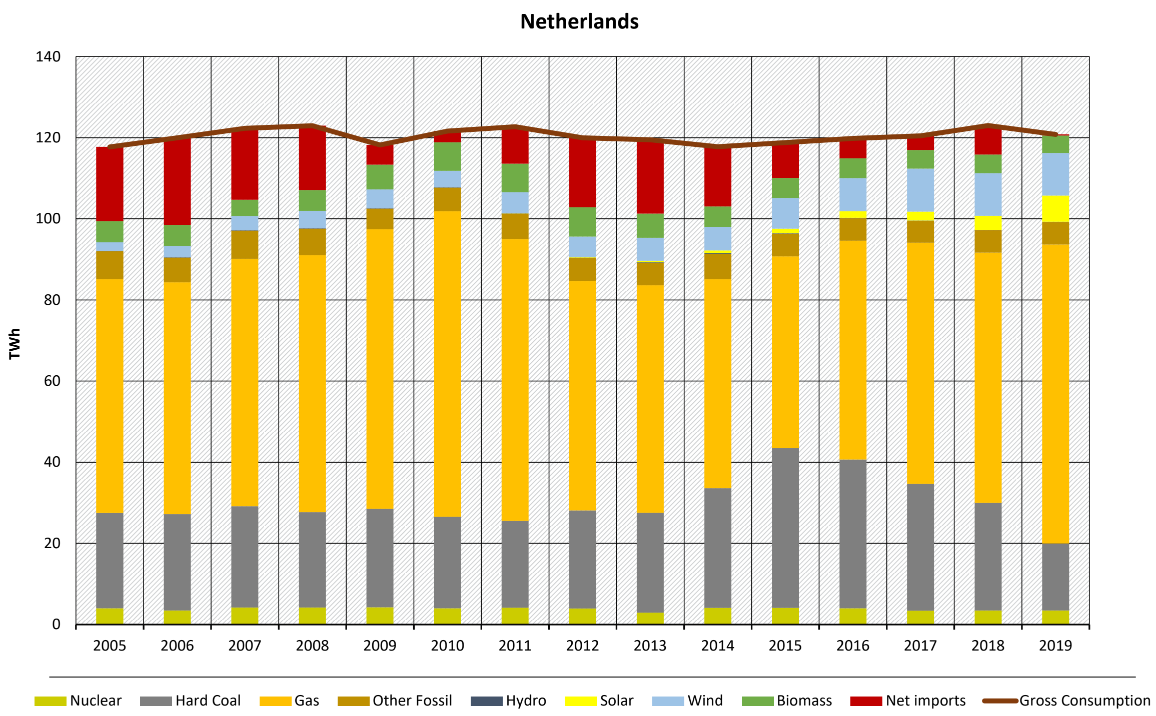
Electricity generation from hard coal fluctuated in the period under review. From 2013 to 2015, power generation from hard coal increased from 25 to 39 TWh due to the construction of new hard coal-fired power plants. The subsequent decommissioning of four hard coal units then led to a decline in electricity production to 27 TWh by 2018. The further decline to 16 TWh in 2019 is also due to lower utilization of hard coal-fired power plants. Hard coal-fired electricity thus still accounted for 36 % of Dutch electricity production in 2015. In 2019, it was only 14 %.

The largest share of Dutch electricity production comes from gas-fired power plants. In the years 2005 to 2011 and again in 2019, gas-fired power accounted for about 60 % of total production. This corresponded to 74 TWh in 2019[8]. Especially in the years with higher coal-fired power production, 2014 to 2017, the share of natural gas dropped to circa 50 %. The lowest electricity production from natural gas between 2005 and 2019 occurred in 2015 with 47 TWh; the maximum was 75 TWh in 2010.

Electricity from other fossil fuels remained at a constant level of around 6 TWh. The same applies to nuclear energy, which contributed around 4 TWh per year.

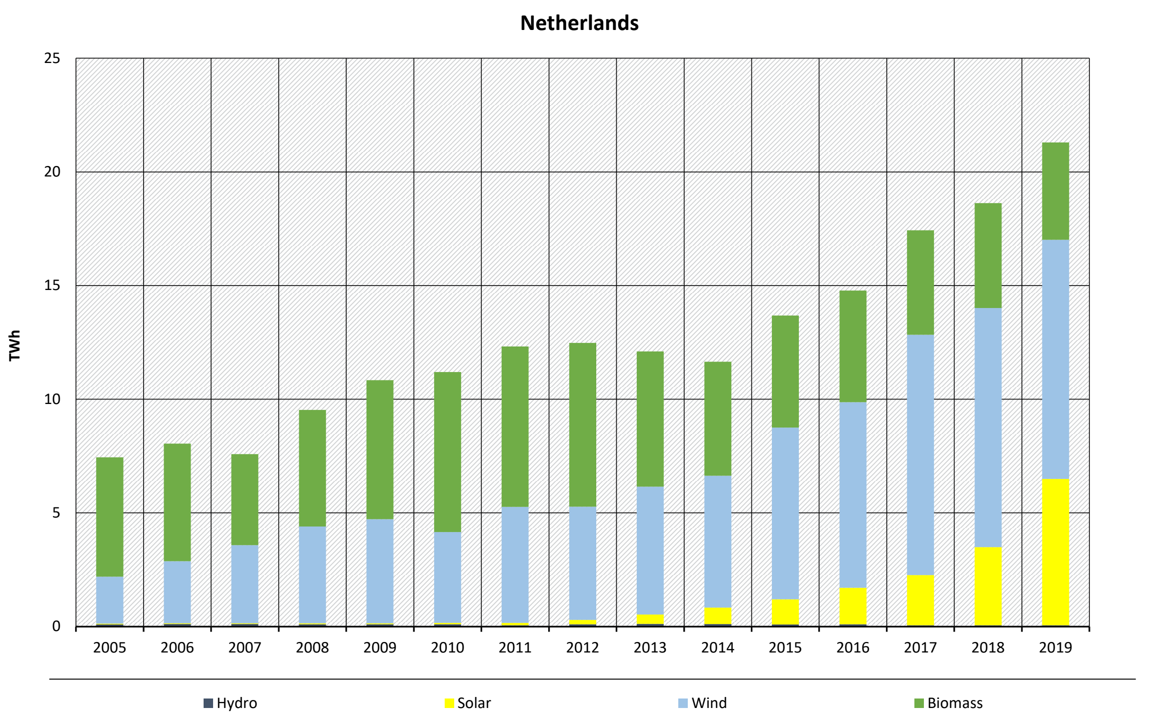
[8] Natural gas is supplied from domestic reserves. Due to earthquakes at the largest field (Groningen Field) and resulting public protests, the government decided to cease production by 2030 and to reduce output at Groningen from 2018 onwards ((van de Graaf et al. 2018)). However, this only affected exports; supply to electricity generation was not affected.

Figure 57: Netherlands: Trends of gross electricity generation and net imports



Source: Ember (2020).

Figure 58: Netherlands: Electricity generation of renewable energies



Source: Ember (2020).

Renewable energies (see Figure 58) in the Netherlands increased from 7 TWh in 2005 to 21 TWh or 18 % of the electricity production in 2019. Biomass had the largest share until 2012.

A large part of the electricity from biomass was generated by co-firing biomass in coal-fired power plants. Our own calculations based on CBS data (CBS Statline 2022) (see Figure 59) show that the share of co-firing in total electricity from biomass was about 65 % in 2005. It declined to about 40 % in the years 2007 to 2012 and fell to below 10 % in 2015 and 2016, with a subsequent upward trend.

The co-firing of biomass has been supported (Xing Zhang 2020) with subsidies under the MEP-scheme ("Environmental Quality of Power Production") from 2003, resulting in 24 co-firing projects under the MEP scheme. As the subsidy was valid for ten years, almost all of the MEP supported co-firing projects expired around 2012/2013. The SDE ("Stimulation of Sustainable Energy Production") scheme was launched in 2008 but covered only biomass co-firing plants smaller than 50 MW. In 2010, SDE was replaced by the SDE+ scheme, but subsidies for co-firing were not available until 2016, when four co-firing projects were subsidized. These were RWE AG's two hard coal-fired power plants Amer 9 and Eemshaven, Uniper's Maasvlakte MPP3 plant and Engie's (later Riverstone's) Maasvlakte New power plant in Rotterdam, which was later shut down due to technical problems (see section 8.3.1).

Figure 59: Netherlands: Share of biomass co-firing in total electricity from biomass

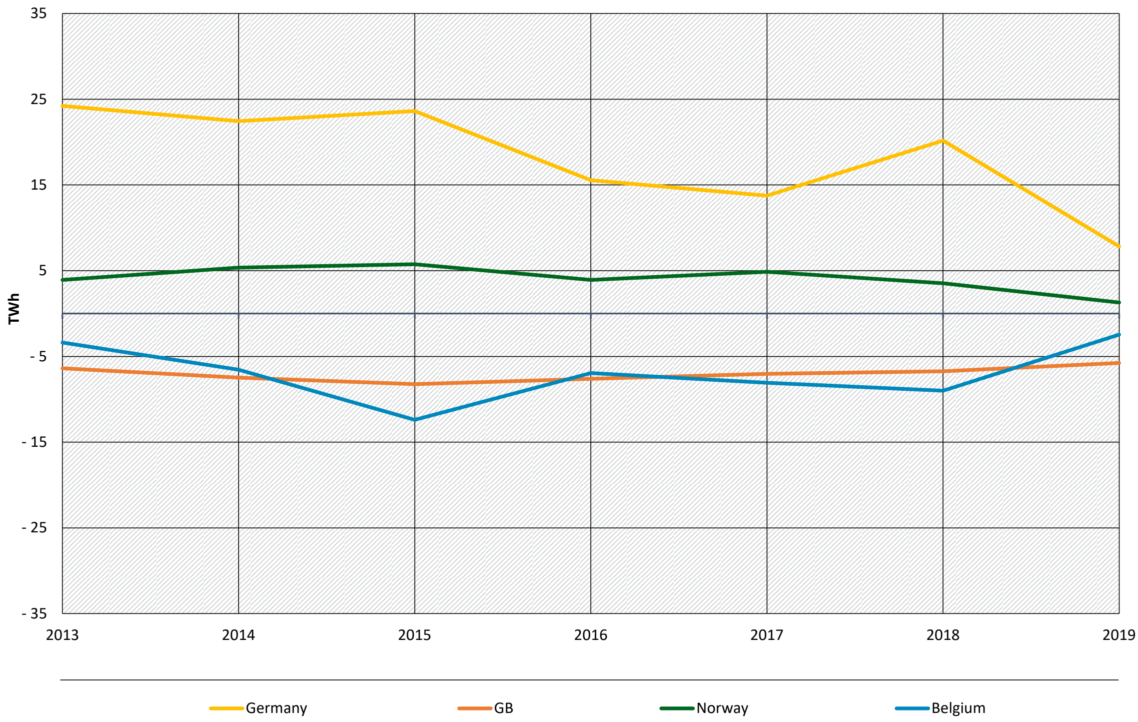
Source: CBS Statline (2022).

Wind energy took the lead in 2013. Whereas in 2005 wind accounted for 2 TWh, in 2019 wind turbines produced almost 11 TWh and thus half of renewable electricity generation. In second place in 2019 was solar power with 6 TWh; biomass comprised the third largest share with 4 TWh. Hydroelectric power accounts for only 0.1 TWh of electricity generation.

Figure 60 shows the physical net import and export flows of electricity between the Netherlands and Germany, Belgium, the UK and Norway between 2013 and 2019. The largest quantities of electricity were imported from Germany in the period under consideration, with a declining trend. Net imports from Norway can also be observed on a constant level. Net exports flow to

Belgium and the UK. Hence, part of the electricity imported from Germany and Norway transits through the Netherlands to serve demand in Belgium and the UK.

Figure 60: Netherlands: Net import (positive) and net export (negative) of electricity, physical exchange with neighbouring countries



Source: ENTSO-E (2013, 2014), and CBS (2015-2019).

8.5 Market setting

8.5.1 Regional market allocation and interconnectors

The electricity market in the Netherlands was liberalized in 2004, which is early when considered in a European context. The transmission system operator (TSO) is TenneT, which is owned by the Dutch Ministry of Finance.

The Netherlands has a long tradition of market coupling with the Tri-Lateral Market Coupling, which integrated the French, Belgian and Dutch day-ahead markets from 2006 to 2010. In 2010, Germany and Luxembourg joined the Trilateral Market Coupling and formed the Market Coupling Western Europe (CWE). The Netherlands has also been part of the Pentalateral Energy Forum, which is a voluntary regional cooperation between Belgium, France, Germany, Luxembourg and the Netherlands, since 2005. Austria joined in 2011. The organization is working on the integration of electricity markets with various measures such as flow-based market coupling, which it introduced in 2015.

There are two Nominated Electricity Market Operators active in the Netherlands: EPEX Spot SE and Nord Pool EMCO AS. Both offer day-ahead and intraday trading.

The Dutch electricity market is physically connected with Belgium, Germany, Norway and the UK, and since 2020 also with Denmark.

Table 29: Netherlands: Maximum forecasted transfer capacity with neighbouring countries in 2021 (MW)

		BE	DE[1]	DK	NO	UK
NL	to	950	3461	700	700	1016
NL	from	950	3016	700	700	1016

Note: [1] For Germany, the values are reported for 2020 based on BNetzA; BKartA 2022.

Source: Own data based on ENTSO-E.

8.5.2 Electricity market design with reference to conventional power generation plants

The Dutch electricity market is an energy-only market. There is no capacity market.

As described above, the Dutch government has decided to phase out coal-fired power generation by 2030. An additional measure is the CO_2 minimum price: After a minimum price for CO_2 had been discussed in the Netherlands for some time, a further step in the legislative process was taken in the summer of 2021 with the adoption of a bill for a minimum CO_2 price in the House of Representatives. It is to act as a tax in addition to the EU ETS price. It starts at 12.30 Euro in 2020 and progressively increases to 31.90 Euro by 2030.

9 Poland

9.1 Key messages

- In 2019, combustion installations (Activity Code 20) in Poland emitted 145 Mt CO_2, which made Poland the 2nd largest emitter (15 %) in this category. Electricity producers account for 87 % of emissions under this category. Between 2013 and 2019, emissions from electricity generators decreased by 20 %.
- Comparing generation with the EU-28 Poland has the highest share of coal in the generation mix. The mix is dominated by hard coal-fired generation (48 %). Lignite-fired generation adds another 26 %. While the latter declined by 24 % between 2013 and 2019, the former decreased by 6 % only. A substantial reduction of coal power generation can be seen predominantly in 2019 when it was substituted by increased generation from natural gas and imports from abroad. Over two thirds of the coal-fired generation fleet was installed before 1990. Gas-fired capacity has increased to 1.8 GW since 2015 and increased its share in generation, especially when CO_2 prices rose in 2018 and 2019.
- Electricity supply from renewables has a low share of 15 % in 2019 although it increased by 43 % between 2013 and 2019. The plan to increase this share to 32 % by 2030 builds on a strong expansion of offshore wind capacities in the Baltic Sea.
- Due to the pivotal role of coal in electricity generation, the average emission factor of gross electricity generation is about 0.8 Mt CO_2 per MWh, which is more than three times higher than the EU-28 average emission factor in 2019.
- Poland changed from being a net exporter of electricity in the Central European electricity system to being an importer. Due to its location in the system, it also provides transit capacity for generation from northern Germany to southern Germany in times of high wind generation in the north (loop flows). These loop flows have declined in recent years with decreasing domestic production in Poland.
- Coal-fired generation is dominated by companies in which the Polish government is the majority shareholder. A coal phase-out is planned by 2049; it applies to hard coal mining only. Poland has frequently announced a plan to construct nuclear power plants, but no concrete plans have materialized yet.

Table 30: Poland: Key figures on the electricity sector in 2019

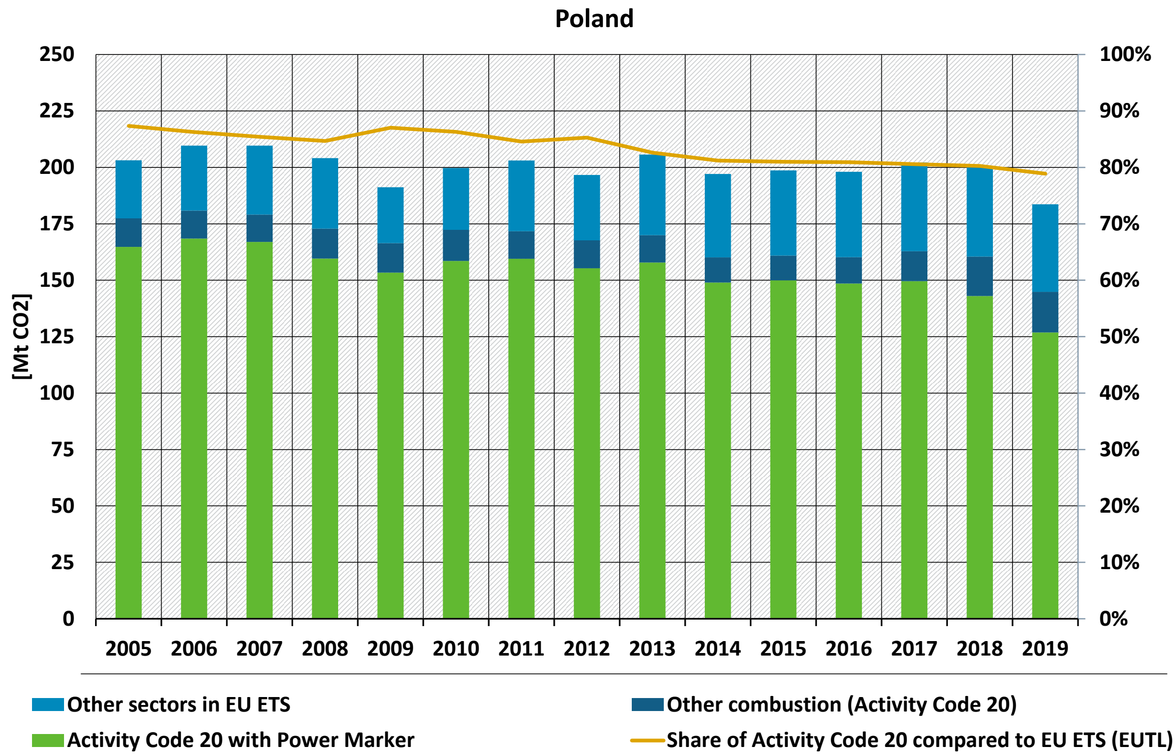
	2019	% change compared to 2013
	CO_2 emissions	
Total CO_2 emissions in 2019 from ETS Activity Code 20 (share of EU-28)	145 Mt CO_2 (15%)	-15%
Total CO_2 emissions from electricity producers[1] (share of combustion installations in the country)	127 Mt CO_2 (88%)	-20%
Emission factor of gross electricity production[2] (relative to EU-28 average)	0.79 t CO_2/MWh (328%)	-19%
	Gross electricity generation	
Total (share of total EU-28)	161 TWh (5%)	-1%
Net electricity imports	10 TWh	-323%
Lignite share in gross generation (share of total gross lignite-fired generation in EU-28)	26% (17%)	-24%
Hard coal share in gross generation (share of total gross hard coal-fired generation in EU-28)	48% (35%)	-6%
RES share in gross generation (target for 2030)[3]	15% (32%)	43%
	Installed capacity	
Total lignite-fired capacity installed (share of total EU-28)	8.8 GW (16%)	-9%
Share of lignite-fired capacity installed before 1990 (share of total EU-28)	73% (12%)	-7%
Total hard coal-fired capacity installed (share of total EU-28)	22 GW (22%)	9%
Share of hard coal-fired capacity installed before 1990 (share of total EU-28)	67% (29%)	-7%

Note: [1] CO_2 emissions from electricity producers based on power plants identified in Oeko-Institut's EU ETS database.
[2] Emission factor calculated based on CO_2 emissions by power plants identified in Oeko-Institut's EU ETS database and gross electricity production reported by Ember (2020).
[3] According to Article 4 (2) Regulation (EU) 2018/1999, MSs have to provide information on their contribution to the Union's binding renewable energy target of at least 32% expressed as renewable energy share on gross final energy consumption. They do so in their NECPs (Article 3(2)(b)). Along with this contribution they also have to report on *estimated trajectories for the sectoral share of renewable energy in final energy consumption from 2021 to 2030 in the electricity, heating and cooling, and transport sector* (see Annex I Regulation (EU) 2018/1999 which sets out the structure of the NECPs)
Source: Own table based on Ember (2020), EC n.d., Europe Beyond Coal (2022), and EEA (2021).

9.2 Emission trends in the EU ETS (combustion installations)

Figure 61 shows CO_2 emissions from the EU ETS in Poland from 2005 to 2019. CO_2 emissions from Activity Code 20 in the EUTL (combustion installations) have seen a decline from contributing 87 % to Poland's total CO_2 emissions covered under the EU ETS since its introduction in 2005, to 85% in 2012 and ending at 79 % in 2019. The electricity sector (Activity Code 20 with oeko-Institut's Power Marker) constantly makes up about 87 % of emissions under Activity Code 20. In 2013, CO_2 emissions from combustion installations have started to decline, while total CO_2 emissions in other EU ETS sectors have slightly increased.

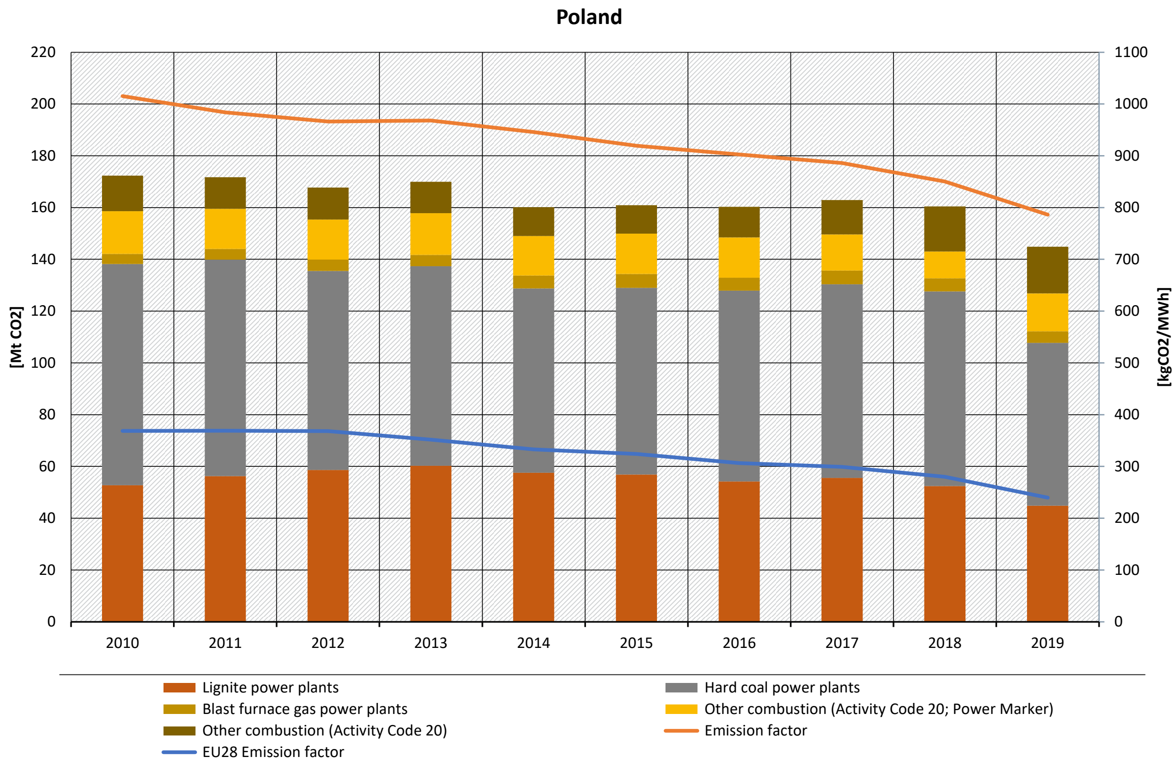
Figure 61: Poland: Emission trends in the EU ETS



Source: z Own compilation of data based on EC n.d., and EEA (2021).

Figure 62 shows CO_2 emissions from Activity Code 20 disaggregated by fuel. They were stable at a level of 170 Mt CO_2 between 2010 and 2013, decreased only slightly to level of 160 Mt CO_2 between 2014 and 2018 and decreased further to less than 150 Mt CO_2 in 2019. Lignite and hard coal-fired power plants accounted for approximately 80 % of all emissions covered by activity code 20, in the years 2010 to 2018. Over these years hard coal power plants contributed 77 Mt CO_2 emissions and lignite power plants 56 Mt CO_2 on average. In 2019, emissions from coal-fired power plants decreased by 13 Mt CO_2 from hard coal power plants and 7 Mt CO_2 from lignite power plants. From 2018 to 2019, emissions from natural gas-fired power plants increased by 4 Mt CO_2. Emissions from blast furnace power stations caused 4 to 5 Mt CO_2 annually, depending on the steel production levels.

Figure 62: Poland: Emission trends from combustion installations in Activity Code 20



Note: Emissions in the category: other combustion (Activity Code 20; Power Marker) are calculated using the deduction method: All emissions with Power Marker minus emissions from lignite and hard coal-fired power plants minus emissions from blast furnace gas power plants.
Source: Europe Beyond Coal (2022), EEA (2021), Ember (2020), and own assignment based on EC n.d..

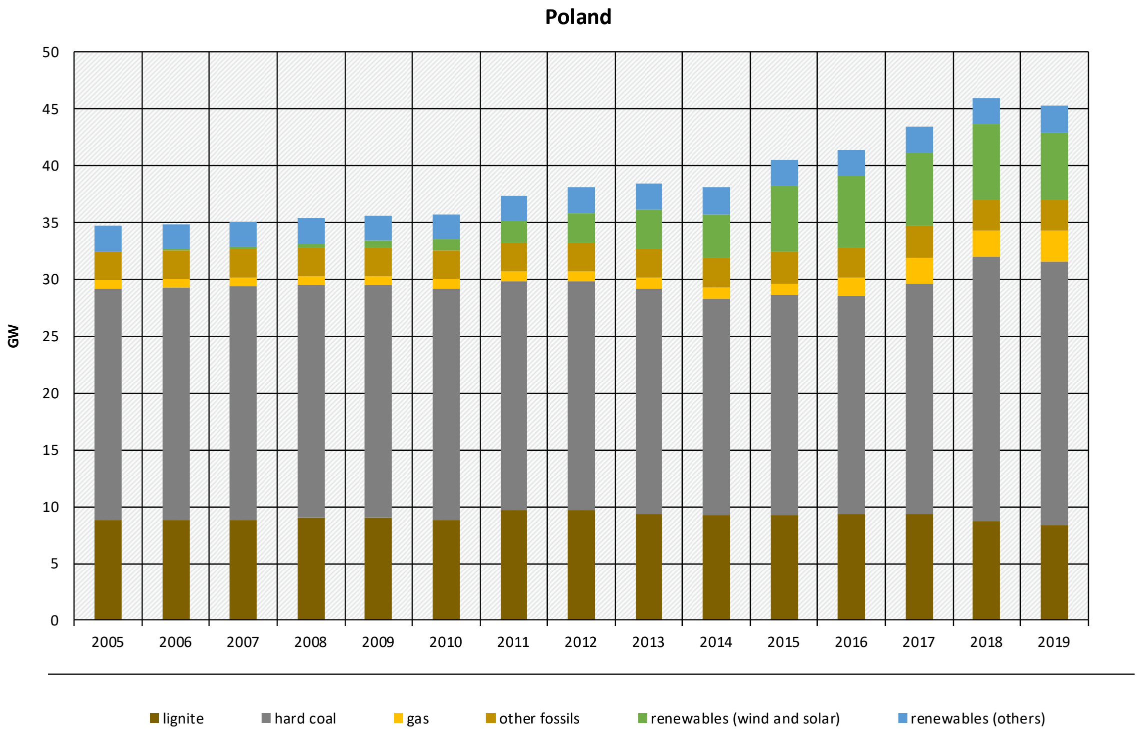
The emission factor of gross electricity generation has seen a strong downward trend from levels above 1000 kg CO_2/MWh in 2010 to 790 kg CO_2/MWh in 2019. It continues to be more than threefold of the EU-28 average.

9.3 Capacity trends

9.3.1 Existing capacities

Figure 63 shows the evolution of installed capacities in the Polish power sector. Capacities are dominated by coal power plants. In 2019, installed capacities of hard coal-fired power generation amounted to 23 GW (51 % of total capacity) hard coal and 8.4 GW (19 % of total capacity) lignite plants. Installed capacities have been quite stable in recent years, but since 2017 installed capacities from hard coal have increased by 3 GW, which is due to new capacities (Opole and Kozienice hard coal-fired power plants) coming online. In contrast, installed capacities of lignite decreased by 1 GW between 2017 and 2019, because old units were decommissioned (e.g. the closure of the Adamow power plant). The ramp-up of renewable capacities started in 2010 and has increased by 25 % per year on average since then. Significant new gas-fired capacities were installed in 2016, 2017, and 2019.

Figure 63: Poland: Evolution of capacity trends by energy carrier



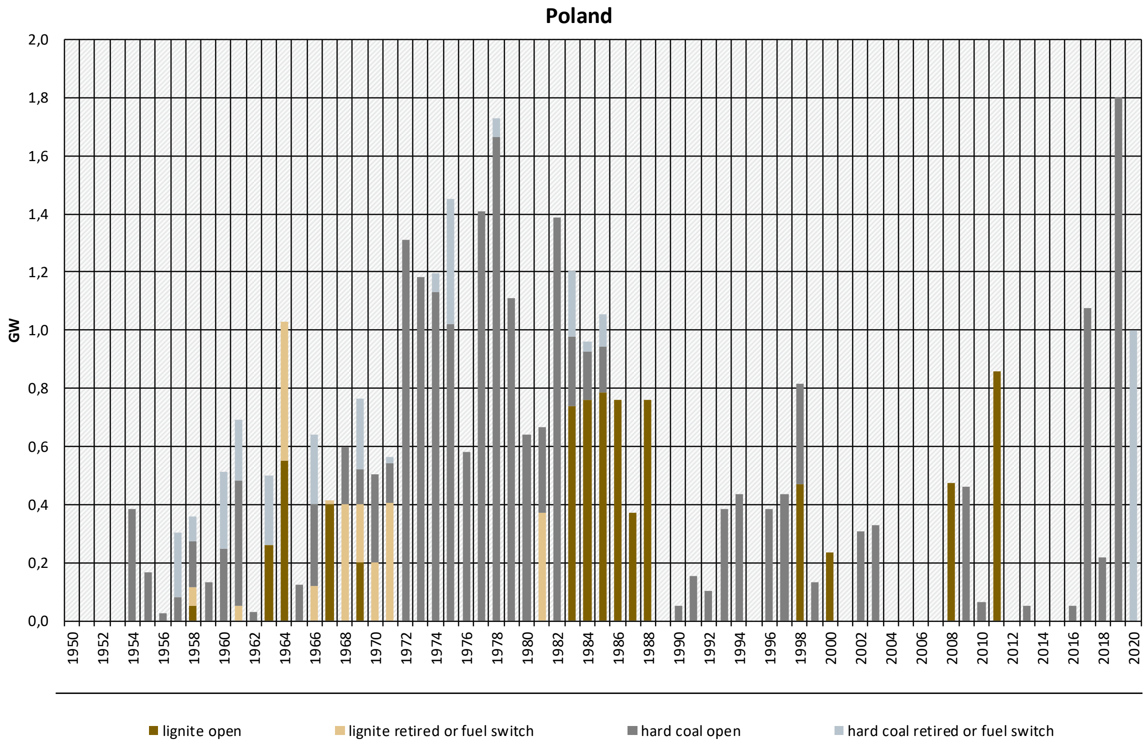
Source: PSE (2020).

Figure 64 shows the age structure of coal-fired power plants in Poland. The graph includes coal plants that are retired by now in a paler shade.

The majority of the capacities was built prior to 1990 (15 GW of hard coal and 6 GW of lignite). Different investment waves are observable:

- The first lignite power plants with a significant capacity of more than 100 MW were commissioned between 1963 and 1971 at three different locations: 6 lignite blocks at Turów plant of 200 MW to 260 MW each, 6 blocks at Patnow I power station with 200 MW each and 5 blocks with 120 MW each at Adamow power station. Most of these blocks are retired today.
- Hard coal-fired power plants were constructed between 1970 and 1982 with a capacity of about 13 GW.
- 11 lignite blocks at the Belchatów plant were constructed between 1983 and 1988 with a capacity of 360 MW each.
- Between 1990 and 2015, a low level of investment can be observed: new power plants are predominantly based on hard coal with only some lignite projects in between. (New plants after 2005 are shown in more detail below.)

Figure 64: Poland: Age structure of lignite and hard coal power plants sorted by year of commissioning



Source: Own illustration based on data from Europe Beyond Coal (2022).

Figure 65 takes a closer look at the newer coal power plants with a commissioning year of 2005 or later as well as power plants under construction.

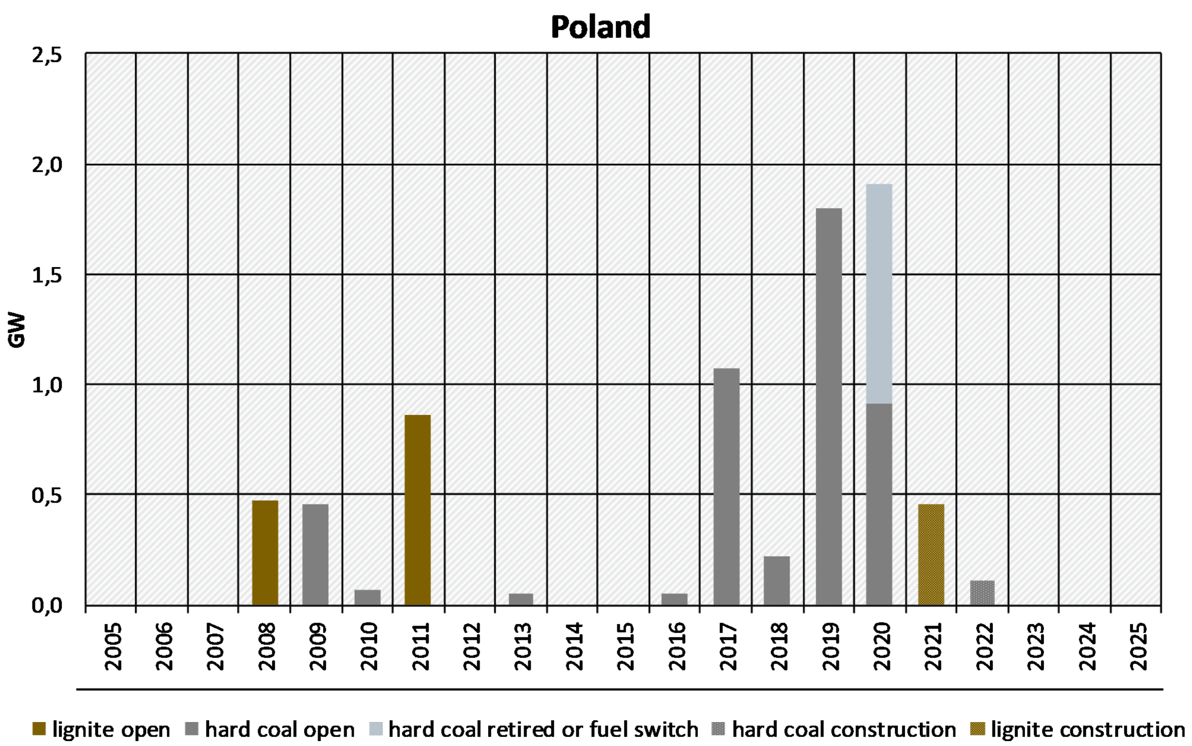
Major capacity additions were lignite units Patnów II with 400 MW in 2008 (owned by ZEPAK) and PGE-owned Belchatów II with 800 MW in 2011. The first new hard coal project after several years was Tauron's block at Lagisza power plant with 460 MW in 2009.

Major hard coal projects were a 1075 MW block at Kozienice power plant in 2017 (owned by Enea), a 220 MW block at Zabrze power station (owned by Fortum), two 900 MW blocks at Opole power plant in 2019 (by PGE) and a 910 MW block at Jaworzno power plant (owned by Tauron) that started operation in November 2020 (Global Energy Monitor Wiki 2020a).

Plants under construction will add a capacity of 460 MW of lignite (PGE-owned Turow B11) to be completed in 2021 and possibly a 109 MW hard coal block at Pulawy power plant by Grupa Azoty. However, there seem to be questions about a possible fuel switch due to climate policies (Magdalena Januszek 2020).

It was planned that the 1000 MW Ostroleka plant would be fuelled by coal; it will, however, be converted to natural gas (NS Energy; Global Energy Monitor Wiki 2021a) (shown as "retired or fuel switch" in the graph in 2020).

Figure 65: Poland: New lignite and hard coal power plants since 2005 including plants under construction, organized by year of commissioning



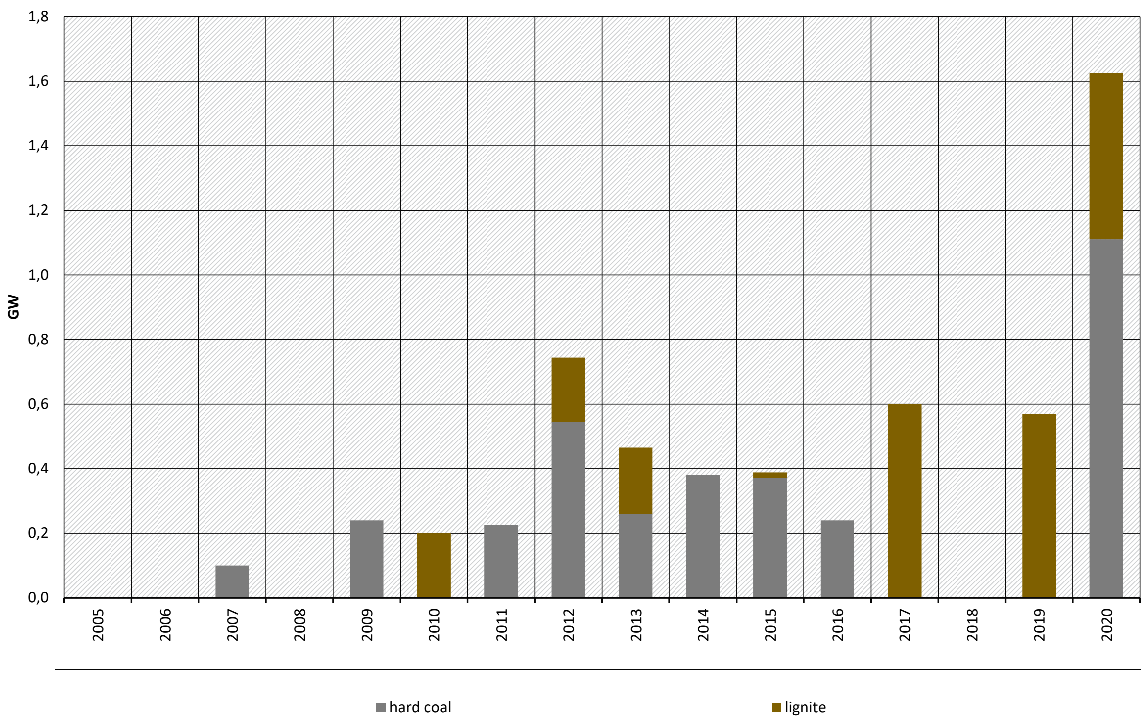
Source: Own illustration based on data from Europe Beyond Coal (2022).

While these new coal-fired power plants were built, the same period since 2005 also saw the closure or fuel switch of coal-fired power plants, as Figure 66 shows.

These include hard coal-fired power plants with a total capacity of almost 3.5 GW (including the above-mentioned 1000 MW Ostroleka C unit from 2020, which is to be converted to natural gas). In addition to 14 smaller hard coal units with capacities below 100 MW (and varying decommissioning dates), 11 blocks with capacities between 110 and 215 MW from the years 1957 to 1975 were decommissioned between 2009 and 2020 as well as two blocks (110 and 225 MW) from 1983 and 1985, which were shut down in 2011 and 2015.

Between 2010 and 2020, 15 lignite units with a total capacity of 2.3 GW were decommissioned. The capacity of 14 of these decommissioned units was between 17 and 200 MW with commissioning dates between 1958 and 1971. The only newer and largest decommissioned unit with 370 MW was from 1981.

Figure 66: Poland: Retired coal-fired plant capacities sorted by retirement date



Source: Own illustration based on data from Europe Beyond Coal (2022).

There are four lignite mining areas in Poland (Koenig et al. 2020): Belchatów (75 % of total production), Turow (10 % of total production), Konin and Adamow (together 15 % of total production). Total lignite production was 67.8 Mt of lignite in 2017. For comparison: lignite production in Germany amounted to 171 Mt lignite in 2017 (Statistik der Kohlenwirtschaft e.V. 2020).

About 30 % of Polish hard coal consumption was imported in 2018 (Euracoal 2020). As hard coal power plants are not exclusively served by one mine as is often the case for lignite power plants, the hard coal mines are not listed individually here.

9.3.2 Future capacity trends

Conventional power plants

The Polish government has repeatedly announced that it wants to keep coal, including mining, in the energy sector until 2049. In November 2022, the Polish State Assets Minister, Jacek Sasin, said that no coal mines should be closed until the first nuclear reactor is commissioned in order to avoid dependence on foreign coal imports (Krzysztoszek 2022).

Poland has frequently stated its intention to construct nuclear power plants. According to the latest draft of the Polish Energy Policy, 1 to 1.5 GW nuclear capacities are planned to be installed by 2033. To date, no concrete plans have materialized, however. The topic remains on the country's energy supply agenda, and involves some initiation steps like a request for state aid for the construction of a nuclear power plant to be approved by the European Commission (Euractiv 2020).

Mining areas

The reserves of the Adamow mining area are depleted. The Konin mining area will be closed by 2030 (operated by the private mining company ZE PAK). Together this comprises 15 % of total lignite mining capacity in Poland. This will also lead to a closure of lignite power plant capacities of 1.6 GW (Patnow power plant) (ZE PAK 1 Oct 2020).

Thus, from 2030 onwards, Poland will have two mining areas, both of which are operated by the state-owned company PGE:

- PGE plans to expand the Turów mine and aims to produce until 2044 (PGE 2019). Current production in 2017 amounted to 6.9 Mt (Koenig et al. 2020). In the period from 2020 to 2038, lignite production is planned to increase to a level between 9 and 11.5 Mt (PGE 2019).
- The Belchatów mine produced 42.6 Mt in 2017. There was a court decision in September 2020 that the operator PGE should negotiate within three months with ClientEarth (claimant) on how emissions can be reduced (ClientEarth 2020).

The coal phase-out by 2049, which Poland announced in September 2020, only applies to hard coal mining (Farand 2020).

Targets for power generation based on renewable energies

The current share of renewable energies in the Polish electricity sector increased to 15 % in 2019. According to the Polish National Renewable Energy Action Plan, the target for the share of renewable electricity for 2020 is 19 % (EC 2010). The Polish NECP foresees a share of renewable energy sources of electricity production of approx. 32 % in 2030 (Ministerstwo Klimatu i Środowiska). In 2005, Poland had introduced a green certificate scheme, which is currently being phased out and replaced by auctions for new RES capacity. The first auctions were held in December 2016. There are plans to build offshore wind parks in the Baltic Sea. The Polish Offshore Wind Act was implemented into law in January 2021 (IEEFA 2021). By 2027, more than 10 GW of capacity could be auctioned (Bernd Radowitz 2020). The first units could be operational by 2025 (Equinor 2020).

9.3.3 Ownership structure of coal power plants

The analysis of the ownership structure focuses on coal-fired generation units, as they account for the largest share of generation capacity in Poland. Table 31 summarizes the ownership structure of lignite- and hard coal-fired generation capacity by company. PGE accounts for almost 50 % of coal-fired generation capacity in Poland, which is divided into 45 % lignite and 55 % hard coal-fired capacity. The Polish government is the majority shareholder in this company. The next two largest companies (ENEA[9]: 19 % and Tauron: 15 %) exclusively own hard coal-fired generation units. ZEPAK[10] is the only other owner of lignite-fired capacities, which accounts for 6 % of coal-fired units. The remaining six companies active on the Polish market all own hard coal-fired units with a total capacity of below 1 GW; these jointly account for 12 % of total coal-fired generation in Poland.

[9] The Polish government is the majority shareholder in this company.

[10] The Polish government is the majority shareholder in this company.

Table 31: Poland: Ownership structure of the coal-fired electricity generation fleet

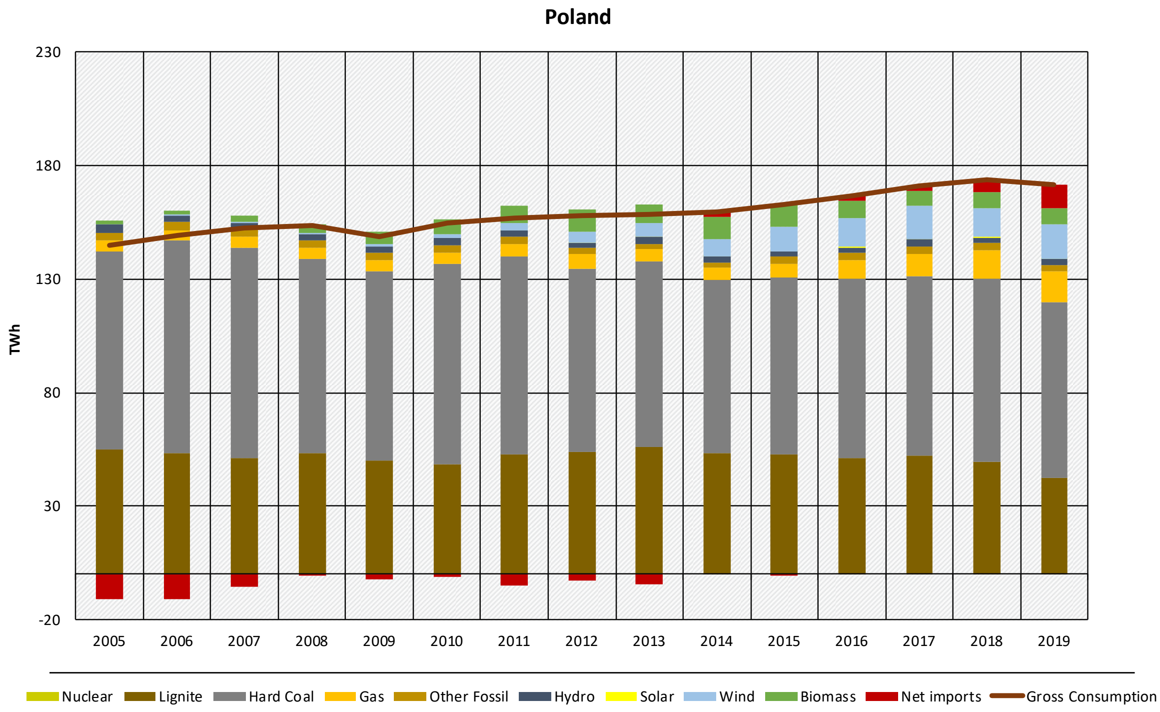
Owner	Gross generation capacity by fuel type [MW]		Company's share of total coal capacity	
	lignite	hard coal	share (%)	cumulative share (%)
PGE	6518	7931	48%	48%
ENEA	0	5761	19%	67%
Tauron	0	4602	15%	82%
ZEPAK	1667	0	6%	88%
PGNiG	0	977	3%	91%
ENERGA	0	743	2%	93%
Veolia	0	698	2%	96%
ČEZ	0	666	2%	98%
Fortum	0	483	2%	99%
EC Będzin SA	0	82	0%	100%

Source: Own table based on Europe Beyond Coal (2022).

9.4 Trends in electricity generation and import balance

Figure 67 details trends in gross electricity consumption, production and net imports. Between 2005 and 2019, gross electricity consumption increased by 27 TWh (19 %). Its evolution can be divided into the following phases: increasing consumption before the economic crisis in 2009, decreasing consumption due to the economic downturn in 2009, recovery and increasing consumption between 2010 and 2017 and stagnation in 2018 and 2019. Electricity production is dominated by coal-fired generation. However, its share in total gross generation decreased from a peak of 92 % in 2007 to 74 % in 2019. The decline in coal-fired generation has not been steady, but came about in several waves: most significantly, hard coal-fired generation dropped by 14 TWh between 2011 and 2014, while lignite-fired generation even increased by 1 TWh between 2011 and 2013. A more gradual decline of about 5 TWh occurred for lignite-fired generation between 2013 and 2016. From 2018 to 2019, both coal-fired generation technologies show a strong decline in production, which is more pronounced for lignite (7 TWh) than for hard coal (4 TWh).

Figure 67: Poland: Trends of gross electricity generation and net imports

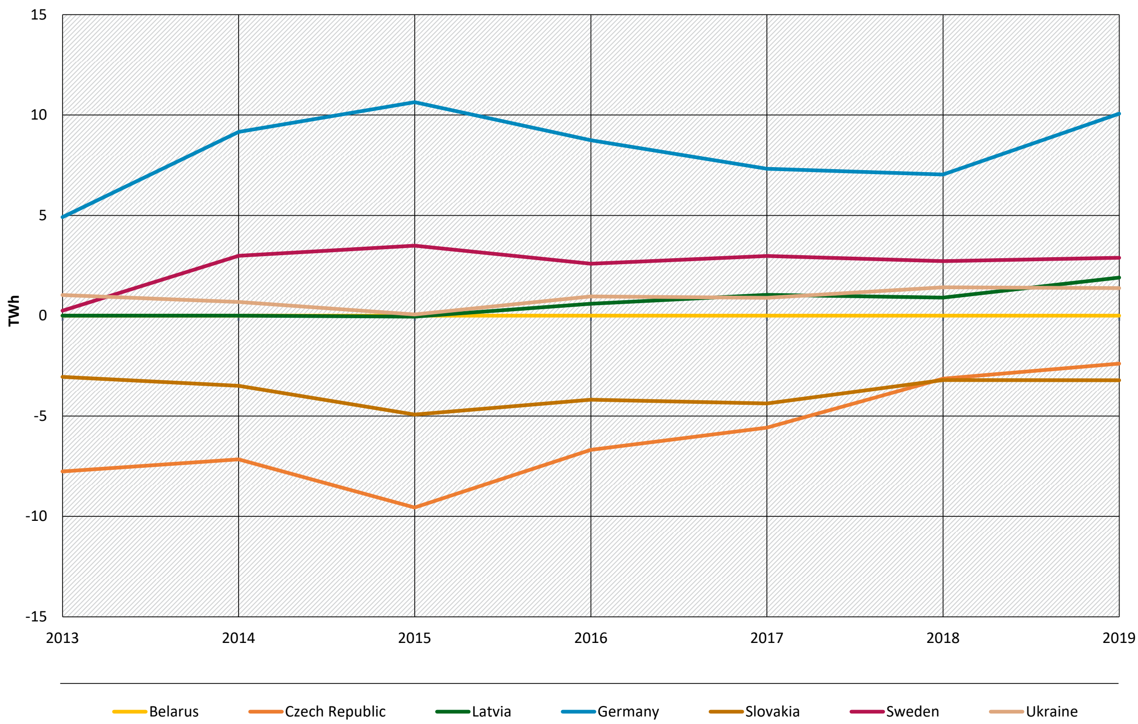


Source: Ember (2020).

Electricity generation from renewables saw a strong rise between 2005 and 2019. The share of renewable electricity increased from 3 % in 2005 to 15 % in 2019. Hydro generation did not contribute to this trend and shows decreasing annual production figures which are dominated by the annual precipitation. Electricity generation from biomass is driven by co-firing in coal-fired powerplants rather than installation of new biomass-based generation units. Accordingly, generation from biomass shows a strong increase from 2 TWh in 2005 to 10 TWh in 2012, followed by a decrease to 7 TWh in 2019 (RAP 2018). Generation from wind shows a strong increase throughout, yet three phases of development can be identified: between 2006 and 2010, annual production increased by 0.3 TWh, ramping up to 1.5 TWh between 2011 and 2014. In the current phase, 2.4 TWh of wind-powered generation are added annually on average. With a generation of 0.2 TWh in 2019, solar-power electricity production does not play a role in Poland (yet).

Gas-fired generation plays a minor but increasing role in the Polish generation mix. Between 2005 and 2015, its share did not change much (3 % in 2005 to 4 % in 2015). With a significant increase in installed capacity between 2016 and 2019, low natural gas prices and increasing CO_2 prices in the EU ETS, gas-fired generation has reached a share of 9 % (14 TWh) in the Polish electricity mix.

Figure 68: Poland: Net import balance with neighbouring countries (actual, physical flows)



Source: PSE (2020).

As detailed in Figure 67, Poland has switched its role from a net exporter of electricity (11 TWh in 2005) to a net importer of the same magnitude (10 TWh in 2019). Figure 68 provides details on the import balance of Poland with its neighbouring countries between 2013 and 2019. There is a stable balance with Slovakia (net exports), Ukraine and Sweden (both net imports). Poland increasingly imports electricity from Latvia.

In an increasing number of hours in the year, electricity prices in Germany decrease due to the high supply of wind generation. This leads to increasing exports from Germany to Poland, resulting in Poland increasingly becoming a net importer of electricity. Due to transmission constraints between wind generation supply in the North and demand centres in the south and west of Germany, some imports result in a loop flow through Poland and the Czech Republic and then back to Germany. Until 2016, the large exports from the Czech Republic suggest that a share of imports from Germany has been channelled through Poland and re-exported towards Germany again. Since 2016, imports from Germany have been on similar, high levels, while exports to Czech Republic have sharply decreased, suggesting that an increasing share of imports from Germany is used to balance domestic consumption, resulting in Poland increasingly becoming a net importer of electricity.

9.5 Market setting

9.5.1 Regional market allocation and interconnectors

The name of the Polish power exchange is TGE – "Towarowa Giełda Energii S.A." [11] (formerly POLPX). TGE offers a spot market, an intraday market and a future market.

Poland has been integrated into the Multi Regional Coupling (MRC) since 2017 (TGE). This means that the electricity exchange with Germany, Sweden and Lithuania is determined by the market outcomes at the respective national marketplaces, taking into account the available net transfer capacities (NTCs). This is in contrast to trade with the Czech Republic, Slovakia and Ukraine, where trade is explicitly determined and controlled by the Transmission System Operator (TSO) PSE. By the end of 2020 market coupling is to be expanded to Czech Republic and Slovakia as well (BiznesAlert 2019). The NTCs of Poland with neighbouring countries are presented in Table 32.

Table 32: Poland: Net transfer capacity with neighbouring countries in 2018 (MW)

		CZ	DE[1]	SK	SE	LT
PL	to	817	1358	500	600	0
PL	from	600	1003	500	600	500

Note: [1] For Germany values are based on BNetzA; BKartA (2022).
Source: Own data based on ENTSO-E.

9.5.2 Electricity market design with reference to conventional power generation plants

A capacity market was introduced in 2018 in Poland. Prices are determined in auctions and reached a level of about 50 €/kW a year. There is a one-year product for existing power plants. New capacities receive payments for 15 years. The new emission limits adopted in the EU Electricity Market Regulation will be binding for new auctions with a "delivery" from 2025 onwards (ICIS 2020). The emission limit for participating in the capacity market is 550 g CO_2/kWh (Article 22(4)) (Europäisches Parlament und Europäischer Rat 2019).Lignite and hard coal power plants have higher specific emissions per kWh and are therefore not eligible to any capacity payment.

From 2007 to 2018, Poland had a support scheme for CHP plants based on certificates. From 2019 onwards, a system is in place that is similar to the German "Kraft-Wärme-Kopplungsgesetz," under which a fixed premium is paid. However, in the Polish system the fixed premium is auctioned (Soltysinski Kawecki Szlezak 2018).

[11] Poland has three Nominated Electricity Market Operators (NEMOs): in addition to TGE also EPEX SPOT and NORD POOL (now EMCO) were nominated. This called for the transmission system operator PSE to prepare an MNA (Multi-NEMO Arrangement) document, which defines the model of the Polish electricity spot market. See also TGE

10 Romania

10.1 Key messages

- In 2019, combustion installations (Activity Code 20) in Romania emitted 22 Mt CO_2, which made Romania the 10th largest emitter (2 %) in this category. Electricity producers account for 81 % of emissions under this category. Between 2013 and 2019, emissions from electricity generators decreased by 25 %.
- Romania has a diverse generation mix. Lignite-fired generation accounted for 22 % of generation in 2019, down from 36 % in 2005. Hard coal contributes a share of 2 % in 2019, while in 2013 generation was 0.4 TWh or 65 % lower. Both hard coal and lignite are supplied from domestic mines. The entire coal-fired generation fleet was installed before 1990. Nuclear power was expanded in 2007 and has provided 20 % of total production since then. Electricity generation from natural gas has contributed around 15 % of total production in the period 2005 to 2019.
- Electricity supply from renewables comprised 41 % of total generation in 2019. Hydro power is a traditional RES-E source in Romania, generating 15 to 20 TWh and contributing 63 % of the RES-E share in 2019. Wind and solar were expanded rapidly between 2010 and 2015, and have stagnated since then.
- The emission factor of gross electricity production of 0.30 t CO_2 per MWh is about 30 % higher than the value for the EU-28 in 2019. With decreasing lignite-fired generation and increasing RES-E supply, it has decreased by more than 25 % since 2013.
- Romania was an exporter of electricity in the European electricity system, in particular in times of high hydro power generation and increasing wind and solar PV supply. With higher CO_2 prices and low hydro power generation, Romania became an importer in 2019.
- A coal phase-out is planned for 2032. In parallel, there are plans to refurbish the existing nuclear power plants and to build a new one by 2031.

Table 33 Romania: Key figures on the electricity sector in 2019

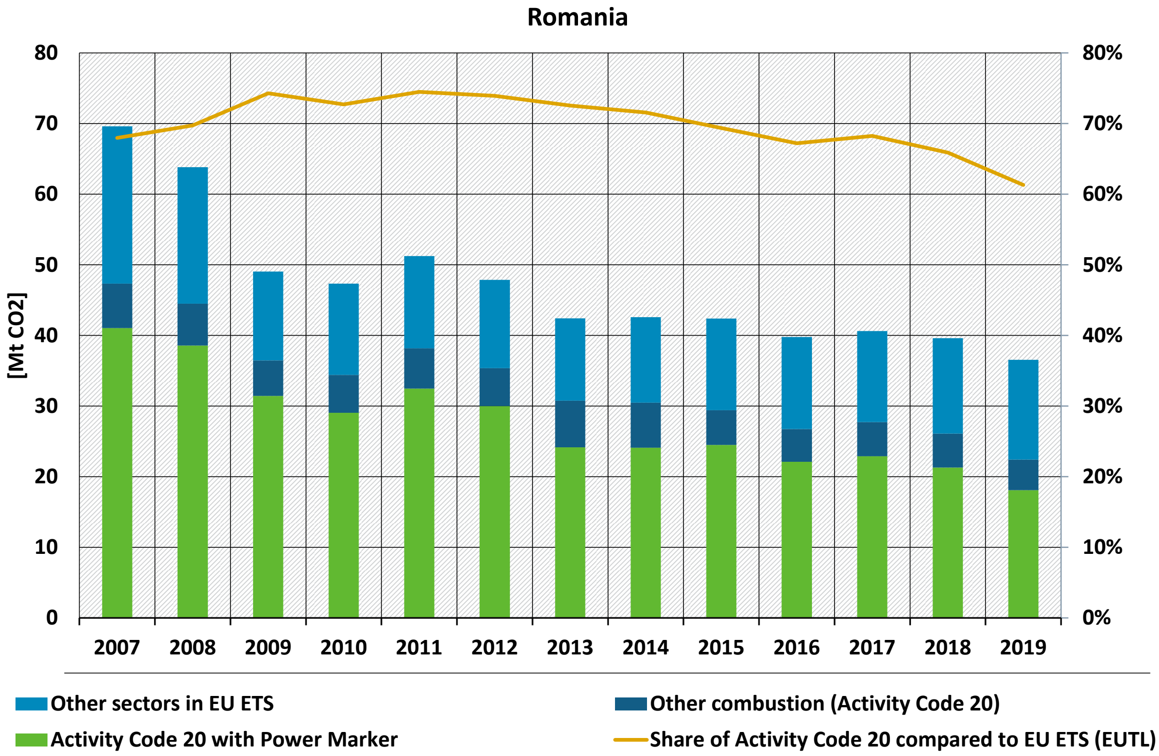
	2019	% change compared to 2013
	CO_2 emissions	
Total CO_2 emissions in 2019 from ETS Activity Code 20 (share of EU-28)	22 Mt CO_2 (2%)	-27%
Total CO_2 emissions from electricity producers[1] (share of combustion installations in the country)	18 Mt CO_2 (81%)	-25%
Emission factor of gross electricity production[2] (relative to EU-28 average)	0.3 t CO_2/MWh (124%)	-28%
	Gross electricity generation	
Total (share of total EU-28)	61 TWh (2%)	4%
Net electricity imports	1 TWh	-174%
Lignite share in gross generation (share of total gross lignite-fired generation in EU-28)	22% (5%)	-19%
Hard coal share in gross generation (share of total gross hard coal-fired generation in EU-28)	2% (1%)	193%
RES share in gross generation (target for 2030)[3]	41% (49%)	19%
	Installed capacity	
Total lignite-fired capacity installed (share of total EU-28)	4.6 GW (9%)	-14%
Share of lignite-fired capacity installed before 1990 (share of total EU-28)	100% (8%)	0%
Total hard coal-fired capacity installed (share of total EU-28)	1.3 GW (1%)	0%
Share of hard coal-fired capacity installed before 1990 (share of total EU-28)	100% (2%)	0%

Note: [1] CO_2 emissions from electricity producers based on power plants identified in Oeko-Institut's EU ETS database.
[2] Emission factor calculated based on CO_2 emissions by power plants identified in Oeko-Institut's EU ETS database and gross electricity production reported by Ember (2020).
[3] According to Article 4 (2) Regulation (EU) 2018/1999, MSs have to provide information on their contribution to the Union's binding renewable energy target of at least 32% expressed as renewable energy share on gross final energy consumption. They do so in their NECPs (Article 3(2)(b)). Along with this contribution they also have to report on *estimated trajectories for the sectoral share of renewable energy in final energy consumption from 2021 to 2030 in the electricity, heating and cooling, and transport sector* (see Annex I Regulation (EU) 2018/1999 which sets out the structure of the NECPs)
Source: Own table based on Ember (2020), EC n.d., Europe Beyond Coal (2022), and EEA (2021).

10.2 Emission trends in the EU ETS (combustion installations)

Figure 69 shows CO_2 emissions from the EU ETS in Romania from 2007, when Romania entered the EU ETS, up to 2019. ETS emissions fell sharply from 70 Mt CO_2 in 2007 to only 49 Mt CO_2 in 2009. Emissions remained at a similar level until another decline occurred in 2013, when emissions amounted to 42 Mt CO_2. In 2019, ETS emissions reached a minimum of 37 Mt CO_2. The share of CO_2 emissions from Activity Code 20 (combustion installations) in total EU ETS emissions increased in 2008/2009 to 74 % due to larger emission reductions in industrial (non-activity 20) installations during the economic crisis; after 2011 this share decreased continuously, reaching a level of 61% in 2019.

Figure 69: Romania: Emission trends in the EU ETS



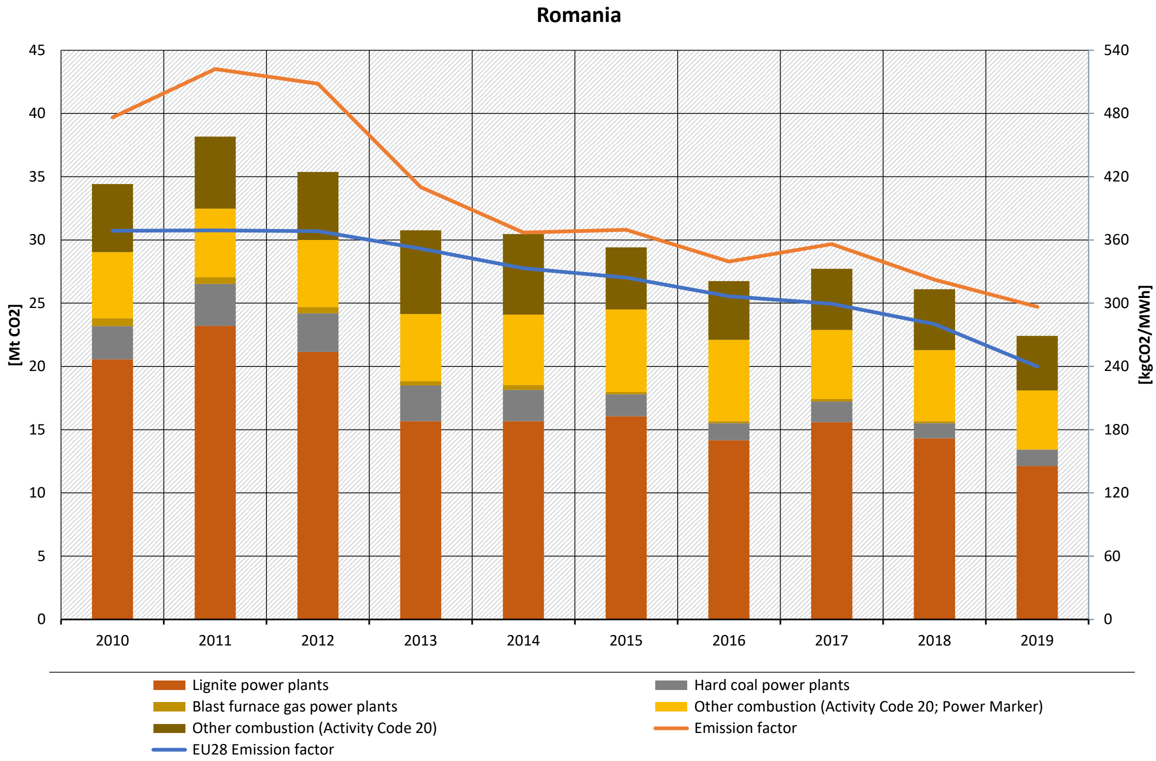
Source: Own compilation of data based on EC n.d., and EEA (2021).

Figure 70 takes a closer look at combustion emissions disaggregated by fuel. CO_2 emissions from Activity Code 20 summed up to almost 35 Mt CO_2 in 2010 and increased to 38 Mt CO_2 in 2011. They decreased to 27 Mt CO_2 in 2016 and after a slight increase in 2017 fell to a level of 22 Mt in 2019.

This decline was mainly due to the decrease of emissions from lignite power plants which accounted for 61 % of combustion emissions in 2011 (23 Mt) and 54 % in 2019 (12 Mt). CO_2 emissions from other fossil power plants fluctuated at around 5 Mt CO_2 in the period considered. Emissions from blast furnace gas power plants are below 1 Mt and decreased to only 0.1 Mt CO_2 in 2019.

Other combustion plants that do not generate electricity account for around 5 Mt CO_2 with a decreasing trend.

Figure 70: Romania: Emission trends from combustion installations in Activity Code 20



Note: Emissions in the category: other combustion (Activity Code 20; Power Marker) are calculated using the deduction method: All emissions with Power Marker minus emissions from lignite and hard coal-fired power plants minus emissions from blast furnace gas power plants.
Source: Own illustration based on data from Europe Beyond Coal (2022), EEA (2021), Ember (2020), and own assignment based on EC n.d..

The emission intensity of gross electricity generation dropped from its peak of 520 kg CO_2/MWh in 2011 to 300 kg CO_2/MWh in 2019. It has remained slightly above the EU-28 average by a factor of 1.2 to 1.3 in recent years.

10.3 Capacity trends

10.3.1 Existing capacities

Figure 71 shows the development of the installed capacity of power plants in Romania from 2009 to 2018.[12]

Lignite power plants had a capacity of 5.4 GW from 2009 to 2015. From 2016, capacity decreased to 4.6 GW. The capacity of hard coal-fired power plants is low and dropped from 1.5 GW in the period 2009 to 2012 to 1.3 GW in the subsequent years.

Natural gas and other fossils are reported together in the Romanian statistics and have a total capacity of about 5.5 GW.

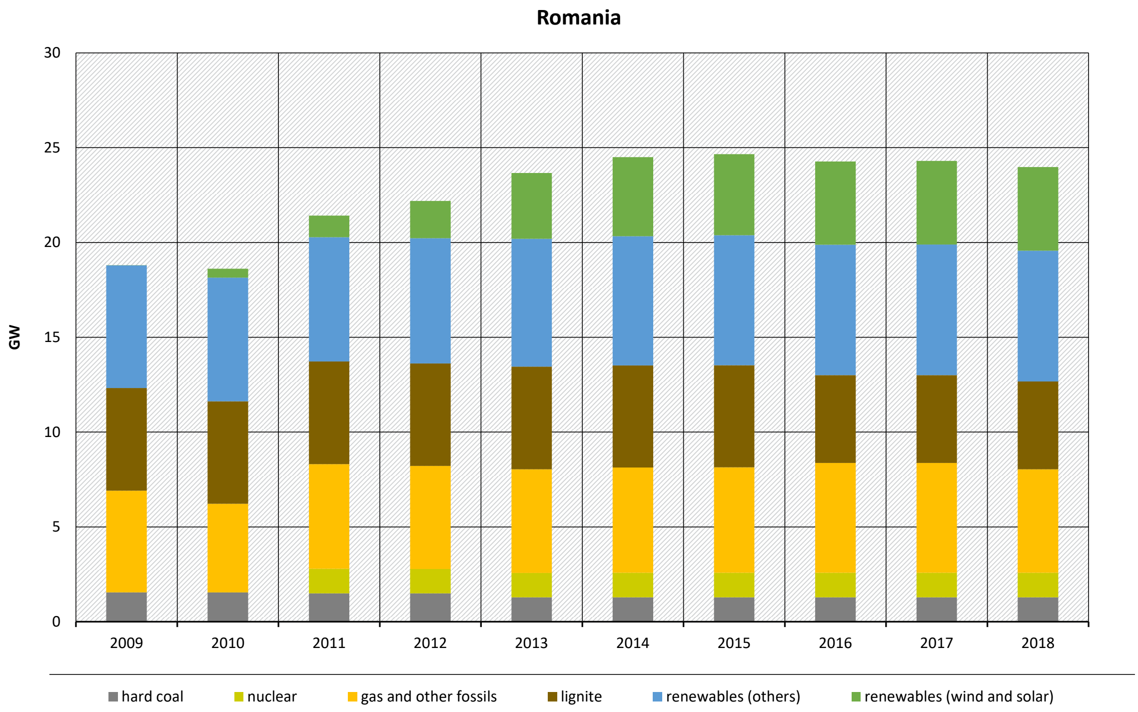
Nuclear power contributed 1.3 GW over the entire period. The only nuclear power plant in operation in Romania is the Cernavoda power plant consisting of two 650 MW units. They started operation in 1996 (block 1) and 2007 (block 2) (World Nuclear Association 2021).

[12] The National Reports of the Romanian regulator ANRE used as a source for gas and other fossils are only available up to 2018.

Wind and solar have increased their capacity significantly, from 0.5 GW in 2010 to 4.4 GW in 2018, of which 3 GW are wind power plants and 1.4 GW solar plants.

Other renewables including biomass, landfill gas, hydro power and geothermal plants total almost 7 GW and have been almost constant over time, dominated by 6.5 GW of traditional hydro power plants.

Figure 71: Romania: Evolution of capacity trends by energy carrier



Note: The more current data available from Romanian Energy Regulatory Authority is for 2018.
Source: Own illustration based on data from Energy Regulatory Office (2016), Energy Regulatory Office 2019, Romanian Energy Regulatory Authority (2019), Europe Beyond Coal (2022).

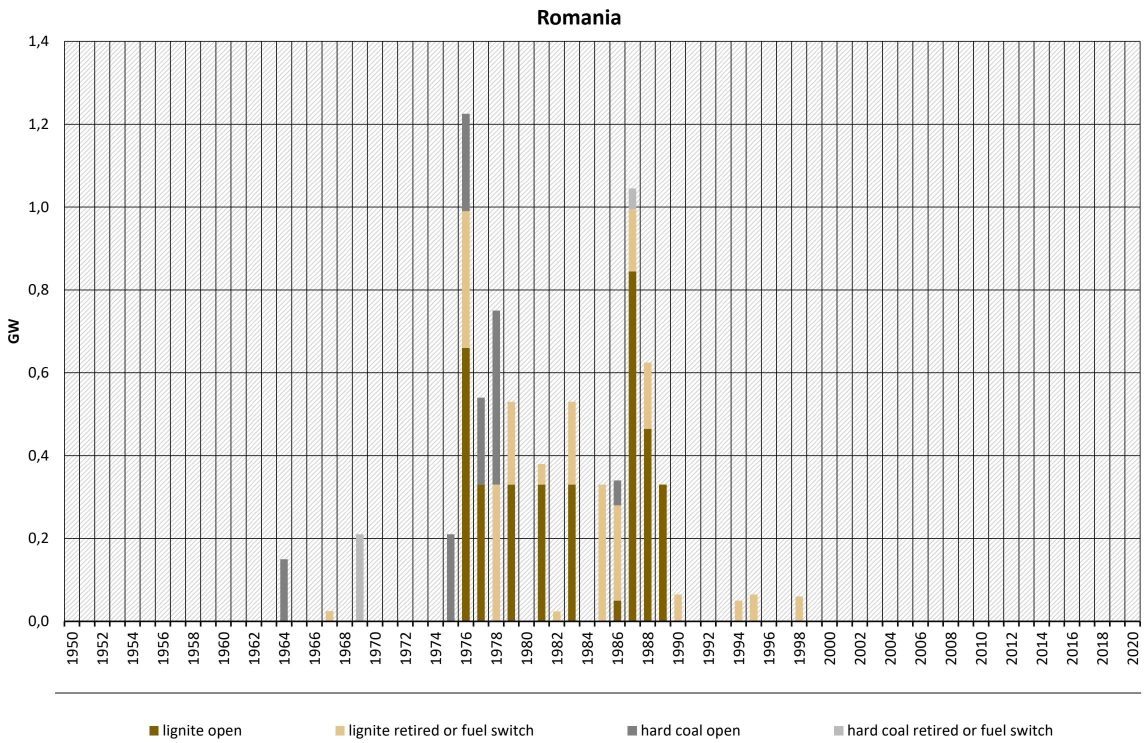
Figure 72 shows the age structure of coal-fired power plants in Romania. The graph includes coal plants that have been retired in a paler shade.

- After a few individual plants were constructed in the 1960s, the data show continuous investment in new coal-fired power plants between 1975 and 1990. After this period, only individual lignite-fired units were added.
- Most of the hard coal capacities were commissioned between 1975 and 1978. The hard coal capacities in Romania are concentrated at three locations. The largest plant is the Mintia power plant with originally 6 units, five with 210 MW each and one with 235 MW. It is located in western Romania in the south-eastern part of the Transylvania region. One of the blocks has been retired (and marked as such in the graph), two are in stand-by mode but still officially open.
- Of the lignite power plants still in operation, the oldest site is Rovinari power plant in the south-west of Gorj county. Four 330 MW units commissioned between 1976 and 1979 are

still running; two 200 MW units of the same generation have been retired (Global Energy Monitor Wiki 2021b).

- The largest lignite power plant in Romania is Turceni power station, which is also located in Gorj county. Of the seven 330 MW blocks, all constructed between 1976 and 1987, three have been retired.
- The youngest lignite-fired power plants still in operation include the Isalnita power plant with two 315 MW units built in 1987 and 1988 and the Craiova II power plant with two 150 MW units commissioned in the same years.

Figure 72: Romania: Age structure of lignite and hard coal power plants sorted by year of commissioning



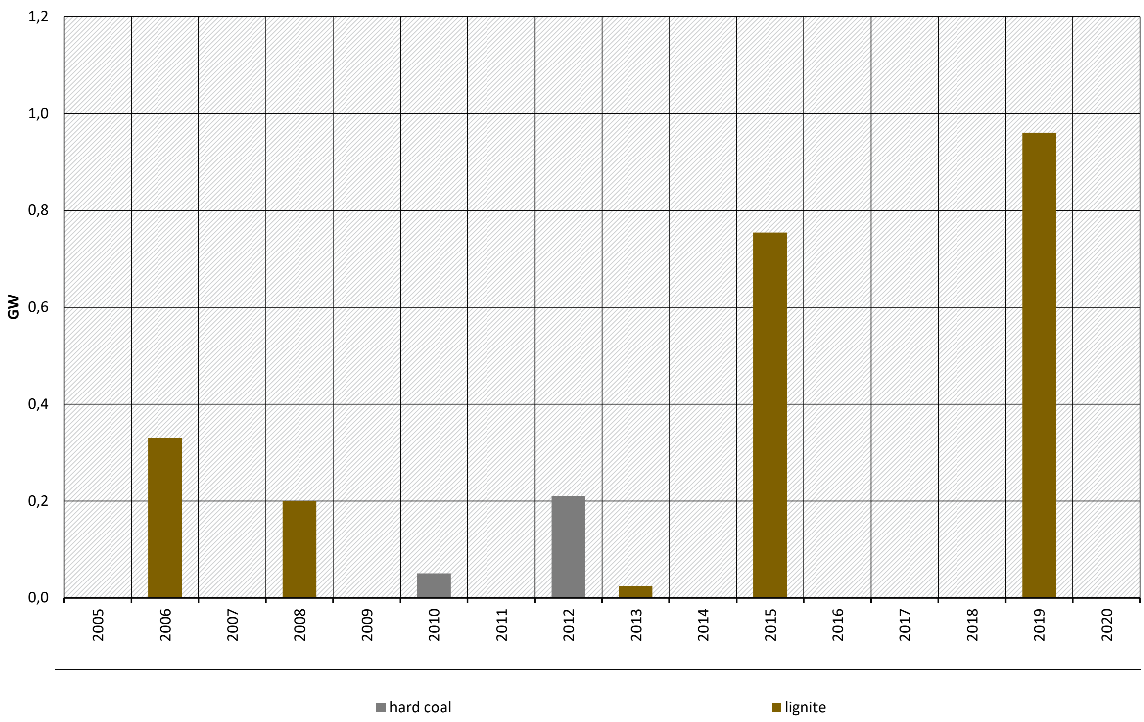
Source: Own illustration based on data from Europe Beyond Coal (2022).

The decommissioning of coal-fired power plants is shown in Figure 73, sorted by retirement date.

23 lignite units with a total capacity of almost 2.3 GW were shut down in the period 2006 to 2019. 18 of these were small blocks with a capacity of 60 MW or less. Three 330 MW blocks at Turceni power station were closed in 2006 (one block) and 2019 (two blocks). Two 200 MW units at Doicesti power station were decommissioned in 2015. These five larger blocks had been commissioned between 1976 and 1985.

Two hard coal units were shut down: a small 50 MW block from 1987 in 2010 and a 210 MW unit from 1969 in 2012.

Figure 73: Romania: Retired coal-fired plant capacities sorted by retirement date



Source: Own illustration based on data from Europe Beyond Coal (2022).

Romania's most important lignite mining area is Oltenia Basin in the south-western Gorj county. It contains 95 % of lignite reserves in Romania and supplies the fuel for the neighbouring Turceni and Rovinari power plants as well as for the Craiova and Isalnita power plants further south. Romanian lignite reserves were reported at 280 Mt for 2018. Annual production in 2018 amounted to 23.5 Mt (Euracoal 2020).

Hard coal mining takes place in the Jiu Valley in the Southern Carpathians. For 2018, hard coal reserves are estimated at 11 Mt and annual production at 0.7 Mt (Euracoal 2020).

10.3.2 Future capacity trends

Conventional power plants

As Figure 72 shows, there have been no new coal-fired power plants in Romania since 1998. In the summer of 2021, Romania decided to phase out coal by 2032. The decision was made as part of Romania's "Recovery and Resilience Plan," a European programme to address the impact of the Covid crisis in Europe, supported by grants and loans from the European Union (Neagu and Taylor 2021). After a positive assessment by the EU Commission in September 2021, the Council approved the plan in October 2021 (Euractiv 2021). The Recovery and Resilience Plan calls for the establishment of a Coal Commission to work out the details of the transition.

The nuclear power plant Cernavoda was originally planned with five units in the 1970s. It is based on a technology transfer from Canada, Italy and the USA and is located on the Danube river in eastern Romania. Only two reactors were realised: Cernavoda 1 supplied electricity for the first time in 1996 after a long construction period that began in 1982. Construction of Cernavoda 2 began in 1983, but was later put on hold. It was not until 2000 that the government decided to complete the second unit, using considerable state funds, and it went online in 2006.

Work on the construction of units 3, 4 and 5 was undertaken by different constellations of companies since the 1980s, but they were never completed.

In October 2020, the Romanian Minister of Economy announced that the USA would finance a refurbishment programme for unit 1 necessary for a life extension, as well as a construction programme for units 3 and 4 with 700 MW each. In March 2021, the state-owned operator Nuclearelectrica said it expected to commission unit 3 by 2031 and start construction around 2024. The largely new reactors will be updated versions of the Canadian Candu 6 reactor type. The operating life is expected to be 30 years with the possibility of a 25-year extension. There seem to be no plans for the completion of unit 5 (World Nuclear Association 2021).

Like other countries, Romania explores the potential of small modular reactors (SMR) for its electricity supply. In March 2019, Nuclearelectrica signed a Memorandum of Understanding with NuScale, a US company specialising in SMRs, to evaluate the construction of an SMR in Romania. At a meeting between the US President's Special Envoy for Climate Action, John Kerry, and Romanian President Klaus Iohannis on the sidelines of the COP26 climate conference in November 2021, it was announced that the first NuScale SMR reactor is to be built in Romania by 2028.

Mining areas

The country's "Recovery and Resilience Plan" (see above) calls not only for the end of coal-generated electricity but also for a phase-out of coal mining by 2032. The plan was confirmed by a corresponding law passed in summer 2022, which additionally contained plans to close the mines and address the socio-economic consequences (Government of Romania 2023).

Targets for power generation based on renewable energies

The Romanian NECP envisaged a renewable share of 49.4 % in gross electricity consumption in 2030. This would correspond to 37 TWh. This is to be realized through a capacity of hydropower plants with 7.6 GW, wind energy with a capacity of 5.3 GW, 5.1 GW of solar power plants and 0.1 GW of biomass-based plants in 2030. The electricity target would be in line with a target of a 30.7 % renewable share in gross final energy consumption (Government of Romania 2020).

The country's Recovery and Resilience Plan (see above) calls for a more ambitious expansion of renewables to a 34 % share of gross final energy consumption (Ministerul Investitiilor si Proiectelor Europene 2021). However, the figures for wind and solar capacities do not go beyond the NECP plans. For 2026, the Recovery and Resilience Plan indicates a total of 7.4 GW from wind and solar, which is even less than the 7.7 GW targeted for wind and solar for 2025 in the NECP.

The main support scheme for renewable electricity in Romania has been a quota system for many years (RES LEGAL Europe 2019d). However, it only applies to capacities that had been accredited by 31 December 2016 (Ecovis 2020). Electricity suppliers and producers are obliged to submit a certain number of green certificates each year, which is calculated by multiplying the mandatory green certificate quota for the year in question (GC/MWh) by the total amount of electricity supplied to end consumers. These green certificates are being traded on a centralized market managed by OPCOM, the Romanian electricity and gas market operator. Demand depends on the legally required quota (Serbia Energy 2015), which has been reduced several times. Failure to comply with this obligation is subject to a penalty. RES installations that meet the prerequisites are entitled to receive green certificates for 15 years.

In 2013, some restrictions were made, including an annual cap on the accreditation of RES power plants (Schönherr 2013). The issuance of part of the initial number of green certificates was suspended for some technologies in the period from 1 July 2013 to 31 March 2017 and beyond until 31 December 2020, in particular for solar energy.

A second funding option for renewable energy plants is the National Rural Development Programme, which offers subsidy programmes for the agricultural sector. These promote, among other things, the use of renewable energy sources for the applicants' own consumption. In addition, a state aid scheme to promote energy production from lesser-used energy sources, namely biomass, biogas and geothermal energy, was approved in April 2017.

The Romanian government is currently working on a new support scheme for electricity from renewable energies based on Contracts for Difference. It is expected to start in 2023 (Reuters 2022b). In addition, the EU-funded Recovery and Resilience Plan will finance the construction of 3 GW of wind and solar plants by 2026 through various tenders beginning in 2022 (PV Magazine 2022).

10.3.3 Ownership structure of coal power plants

Table 34 shows the list of companies owning coal-fired power plants in Romania. 3570 MW, representing 72 % of the coal-fired power plant capacity, belong to Complexul Energetic Oltenia S.A., a network of power plants (Craiova II, Isalnita, Rovinari and Turceni) and lignite mines in Gorj, Vâlce and Mehedinţi. The Oltenia energy complex was established in 2012 through the merger of Societatea Naţionala a Lignitului Oltenia, the former mining company, with the Turceni, Rovinari and Craiova power plants. The complex produces 95 % of the country's lignite (Global Energy Monitor Wiki 2022a). CE Oltenia owns all the lignite units still in operation in Romania, with the exception of two 50 MW units owned by Valcea County Council.

State-owned Complexul Energetic Hunedoara S.A. is the largest owner of hard coal capacity, namely of five units at the Mintia power plant (with a total of 1075 MW) and the 150 MW Paroseni power plant built in 1964. The company also operates hard coal mines in the Jiu Valley.

One additional hard coal-fired power plant is the 60 MW Iasi II unit built in 1986 owned by Veolia.

Table 34: Romania: Ownership structure of the coal-fired electricity generation fleet

Owner	Gross generation capacity by fuel type [MW]		Company's share of total coal capacity	
	lignite	hard coal	share (%)	cumulative share (%)
CE Oltenia SA	3570	0	72%	72%
CE Hunedoara SA	0	1225	25%	97%
Valcea County Council	100	0	2%	99%
Veolia	0	60	1%	100%

Source: Own table based on Europe Beyond Coal (2022).

10.4 Trends in electricity generation and import balance

Figure 74 shows gross electricity generation in Romania between 2005 and 2019, broken down by fuel, as well as gross consumption and net exports.

Gross consumption amounted to around 60 TWh in the indicated period, with decreases in 2009, due to the economic crisis, and in 2013. Romania was a net exporter of electricity in the entire period except in 2012 and 2019.

Electricity generation from nuclear power plants increased between 2005 and 2008 with the commissioning of the second nuclear reactor Cernavoda 2. Since then, about 11 TWh to 12 TWh have been annually generated by the two nuclear power plants.

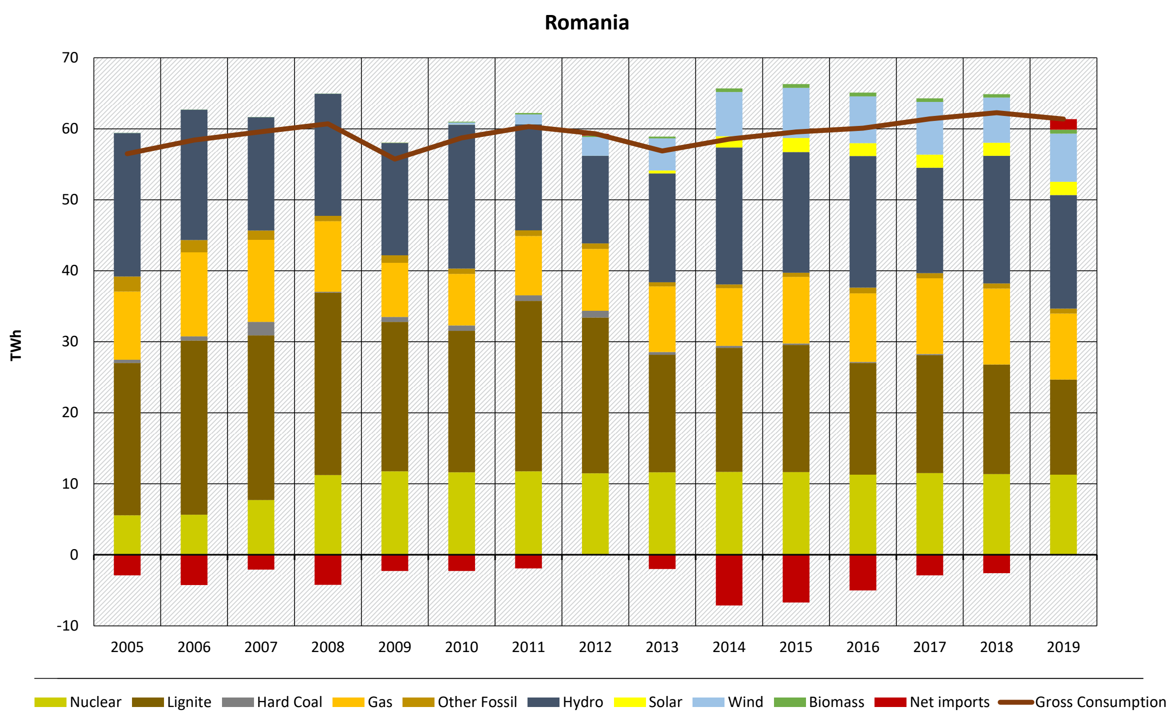
Electricity generation from lignite power plants fluctuated between 20 TWh and 26 TWh between 2005 and 2011. Since then, lignite generation has declined to 13 TWh in 2019.

Generation from hard coal-fired power plants plays a minor role in Romania with about 1 TWh or less in most years.

Electricity generation from gas-fired power plants amounted to approx. 10 TWh in recent years. After it had dropped from almost 12 TWh in 2006 and 2007 to about 7 TWh in 2009 and 2010, it showed an increasing trend in the subsequent years.

Electricity from other fossil fuels declined from 2 TWh in 2005 to less than 1 TWh in 2019.

Figure 74: Romania: Trends of gross electricity generation and net imports



Source: Ember (2020).

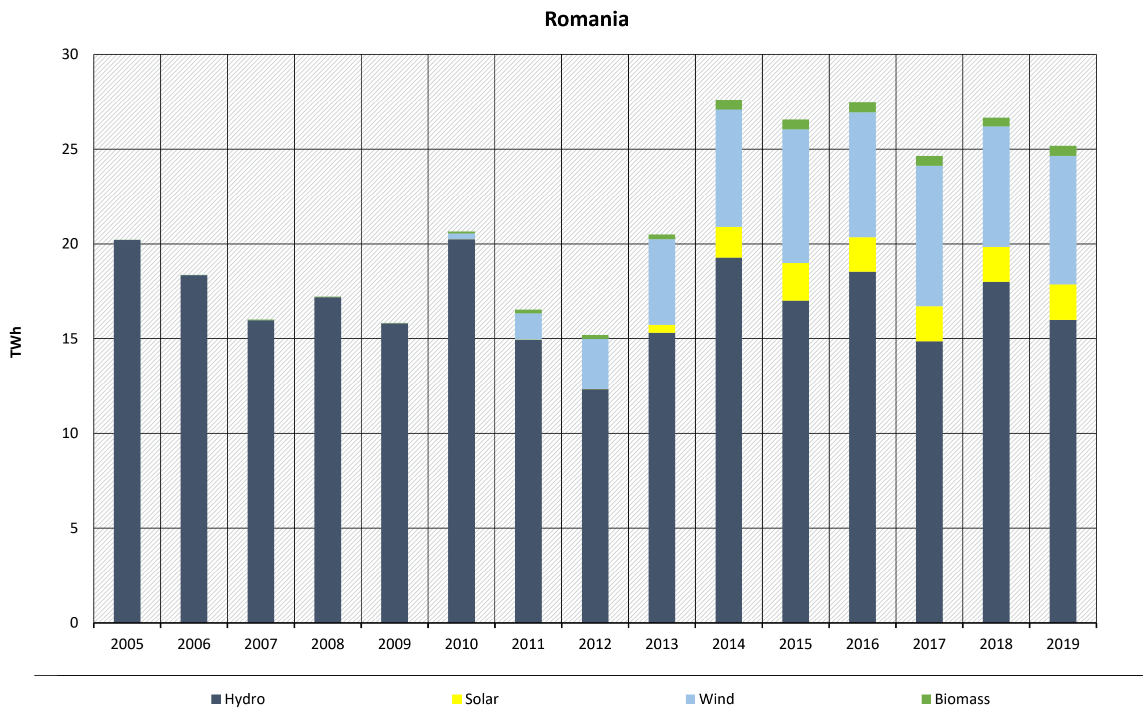
Electricity generation from the main renewable energy sources in Romania is shown in Figure 75. Electricity from hydro power is a traditional form of renewable electricity generation in Romania and the renewable technology with the largest share. It varied strongly between 12 TWh and 20 TWh in the period considered.

Since 2010, wind-based generation started to play a role in the renewable mix. It increased from 0.3 TWh in 2010 to about 7 TWh in 2019.

Solar energy-based generation delivered only 0.4 TWh im 2013 but increased to almost 2 TWh in 2015. It has been constant since then.

Biomass delivered only 0.1 TWh in 2010 and grew to 0.5 TWh in 2014. There has been no substantial increase since then.

Figure 75: Romania: Electricity generation of renewable energies

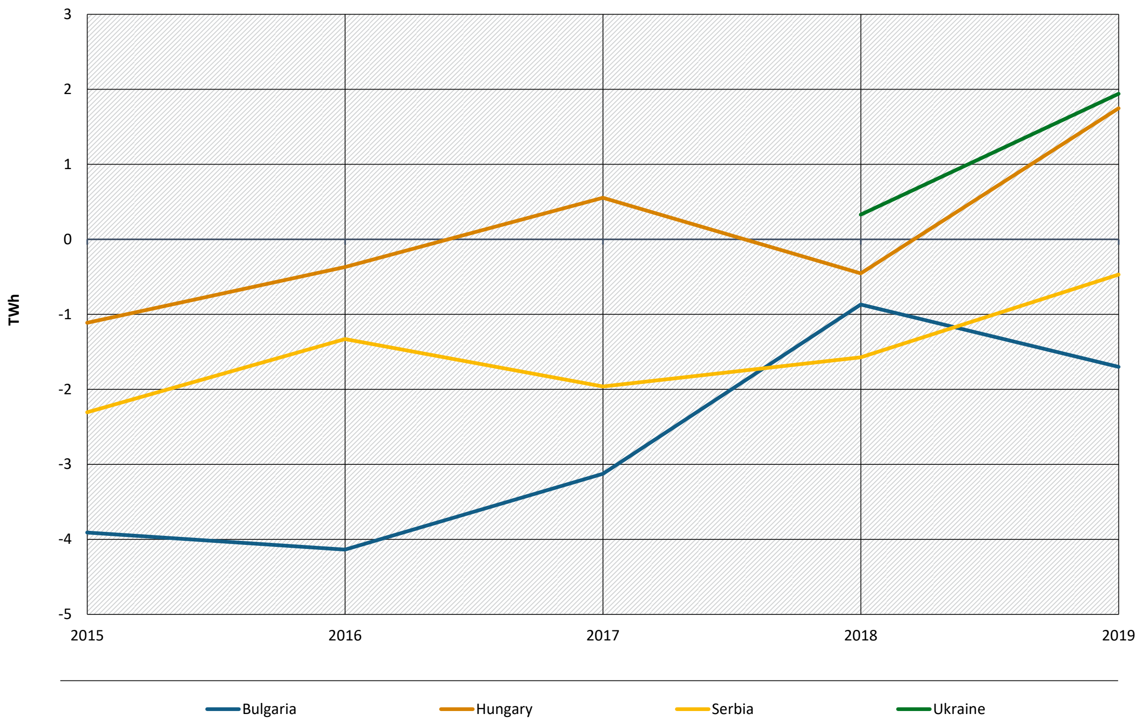


Source: Ember (2020).

Figure 76 shows the physical net import and export flows of electricity between Romania and the neighbouring countries between 2015 and 2020. Romania has electric connections to four countries: Bulgaria, Hungary, Serbia and Ukraine. There are plans to connect Romania and Moldova in the future (Rosca 2019).

Physical net exports took place in all years from Romania to Bulgaria and Serbia. Net imports came from Ukraine since 2018. The exchange between Romania and Hungary switched between net exports (2015, 2016 and 2018) and net imports (2017, 2019).

Figure 76: Romania: Net import (positive) and net export (negative) of electricity, physical exchange with neighbouring countries



Source: ENTSO-E (2005-2015), Bundesnetzagentur | SMARD.de (2016-2020).

10.5 Market setting

10.5.1 Regional market allocation and interconnectors

The designated NEMO (Nominated Electricity Market Operator) in Romania is OPCOM S.A. (ACER 2022)

In 2014, Romania joined the market coupling with the Czech Republic, Slovakia and Hungary to form the 4M Market Coupling project (4MMC). Bulgaria was included by means of the Bulgarian-Romanian Market Coupling project (Spasic 2021) and by coupling with the Multi Regional Coupling (MRC) area, both of which occurred in 2021. The next step, expected for 2022, is to introduce flow-based implicit allocation for the Core Capacity Calculation Region including MRC and 4MMC areas.

Table 35 shows the maximum forecasted transfer capacities between Romania and its neighbours according to ENTSO-E data.

Table 35: Romania: Maximum forecasted transfer capacity with neighbouring countries in 2021 (MW)

		BG	HU	RS	UA
RO	to	400	350	250	100
RO	from	400	350	250	100

Source: Own data based on ENTSO-E.

10.5.2 Electricity market design with reference to conventional power generation plants

In Romania, there is neither a capacity market, nor any other officially notified capacity mechanism. However, there was a mechanism that functioned like capacity payments in the period 2013 to 2017. As it was introduced in 2013, before the European legislation came into force that would have required notification to the European Union (starting in 2014), this mechanism did not need to be approved by the European Union. Under the relevant decree, the Romanian transmission system operator Transelectrica was obliged to buy a certain amount of electricity from two coal-fired power plants, one belonging to Oltenia (where the scheme applied until 2015) and one to Hunedoara (until 2017). Critics say the two companies pressured the Romanian government into the decree after a boom in renewable energy in 2012 and 2013 caused the profits of coal-fired power plant operators to shrink (Gusilov 2018).

11 Spain

11.1 Key messages

- In 2019, combustion installations (Activity Code 20) in Spain emitted 55 Mt CO_2, which made Spain the 5th largest emitter (6 %) in this category. Electricity producers account for 75 % of emissions under this category. Between 2013 and 2019, emissions from electricity generators decreased by 31 %.
- Spain has a diverse generation mix. Gas-fired generation accounts for about 30 % of gross electricity production in 2019. Coal contributed a share of 4 % in 2019; its generation has decreased by more than two thirds since 2013. All lignite-fired units and more than 80 % of the hard coal-fired units were installed before 1990. Nuclear power contributes a constant share of 20 %. Electricity generation from other fossil fuels (such as waste gases from refineries and steelmaking) halved between 2005 and 2013 and comprised only 6 % of total generation in 2019.
- The emission factor of gross electricity production is 0.15 t CO_2 per MWh, which is 40 % below the level for the EU-28. With decreasing generation by coal and other fossil fuels, the emission factor has decreased by almost 30 % since 2013.
- Electricity supply from renewables comprised 37 % of total generation in 2019. Hydro power is a traditional RES-E source in Spain with a strong variation in generation levels between 21 TWh and 46 TWh. Solar PV and wind generation saw a boom between 2005 and 2013. Due to a change in regulation, the RES-E build-up has halted since 2014 and the RES-E share decreased from its 41 % peak in 2013 due to a strong decrease in electricity generation from hydro power between 2013 and 2019. Installation numbers gained new traction in 2019. Ambitious plans to increase the RES-E share to 74 % by 2030 through a new ramp-up in wind and solar capacities are backed by a new support scheme.
- Spain has changed its position in the Southwest-European electricity system from being a net exporter until 2015 to becoming a net importer since then.
- A coal phase-out is planned for 2025; the last lignite-fired unit closed in 2020. It is planned that nuclear power will be phased out between 2025 and 2035, entailing life-time extension beyond the 40-year limit. A capacity market is intended to contribute to the installation of a total of 20 GW of storage capacity by 2030.

Table 36 Spain: Key figures on the electricity sector in 2019

	2019	% change compared to 2013
	CO_2 emissions	
Total CO_2 emissions in 2019 from ETS Activity Code 20 (share of EU-28)	55 Mt CO_2 (6%)	-22%
Total CO_2 emissions from electricity producers[1] (share of combustion installations in the country)	41 Mt CO_2 (75%)	-31%
Emission factor of gross electricity production[2] (relative to EU-28 average)	0.15 t CO_2/MWh (63%)	-27%
	Gross electricity generation	
Total (share of total EU-28)	273 TWh (8%)	-4%
Net electricity imports	7 TWh	-196%
Lignite share in gross generation (share of total gross lignite-fired generation in EU-28)	0.2% (0.2%)	-
Hard coal share in gross generation (share of total gross hard coal-fired generation in EU-28)	4% (5%)	-74%
RES share in gross generation (target for 2030)[3]	37% (74%)	-8%
	Installed capacity	
Total lignite-fired capacity installed (share of total EU-28)	1.1 GW (2%)	0%
Share of lignite-fired capacity installed before 1990 (share of total EU-28)	100% (2%)	0%
Total hard coal-fired capacity installed (share of total EU-28)	9 GW (9%)	-14%
Share of hard coal-fired capacity installed before 1990 (share of total EU-28)	83% (8%)	-9%

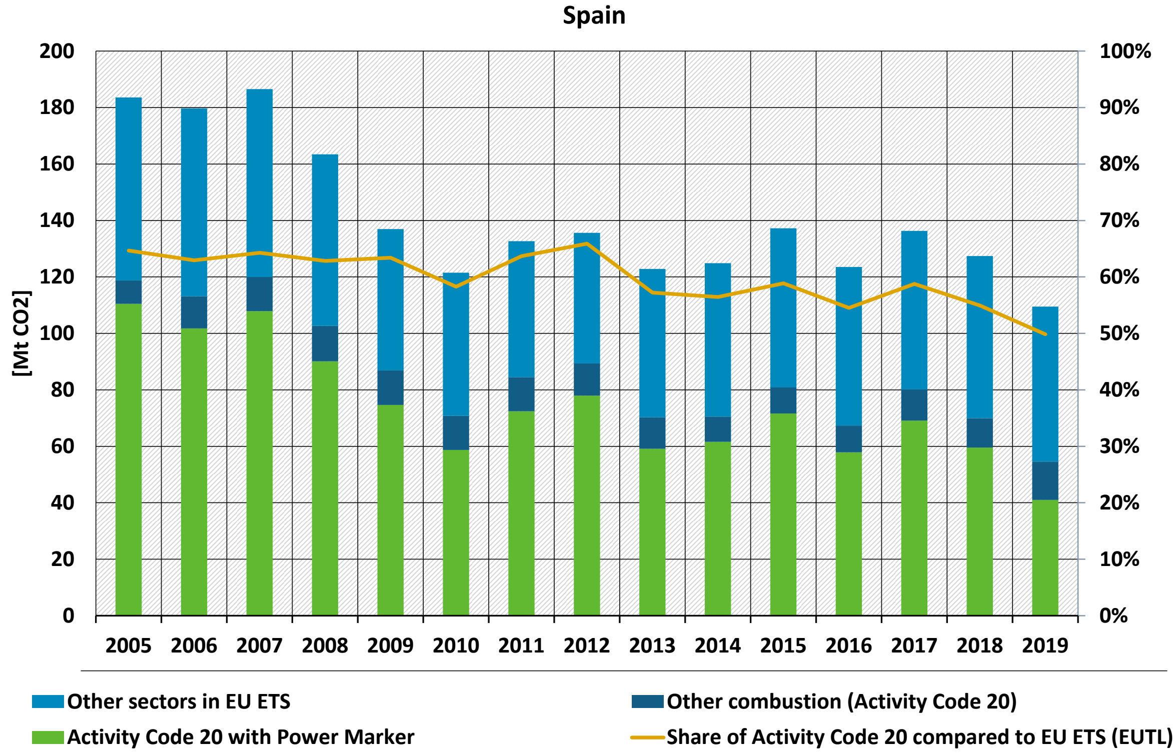
Note: [1] CO_2 emissions from electricity producers based on power plants identified in Oeko-Institut's EU ETS database.
[2] Emission factor calculated based on CO_2 emissions by power plants identified in Oeko-Institut's EU ETS database and gross electricity production reported by Ember (2020).
[3] According to Article 4 (2) Regulation (EU) 2018/1999, MSs have to provide information on their contribution to the Union's binding renewable energy target of at least 32% expressed as renewable energy share on gross final energy consumption. They do so in their NECPs (Article 3(2)(b)). Along with this contribution they also have to report on *estimated trajectories for the sectoral share of renewable energy in final energy consumption from 2021 to 2030 in the electricity, heating and cooling, and transport sector* (see Annex I Regulation (EU) 2018/1999 which sets out the structure of the NECPs)
Source: Own table based on Ember (2020), EC n.d., Europe Beyond Coal (2022), and EEA (2021).

11.2 Emission trends in the EU ETS (combustion installations)

Figure 77 shows CO_2 emissions from the EU ETS in Spain from 2005 to 2019. ETS emissions fell from over 180 Mt CO_2 in 2005-2007 to around 120 Mt CO_2 in 2010, fluctuating at around 130 Mt CO_2 in the subsequent years and decreasing to just 110 Mt CO_2 by 2019.

Emissions from combustion installations followed a similar trend, with a slightly steeper decline in recent years. CO_2 emissions from combustion plants fell from 120 Mt CO_2 in 2005 to around 70 Mt CO_2 in 2010 and rose again to around 90 Mt CO_2 in 2012. The share of combustion emissions in total ETS emissions ranged between 58 % and 66 % from 2005 to 2012. Since 2013, the share has decreased to levels between 57 % and 50 %, with absolute levels of emissions from combustion plants ranging between 70 Mt CO_2 and 80 Mt CO_2 until 2018 and falling to 55 Mt CO_2 in 2019.

Figure 77: Spain: Emission trends in the EU ETS



Source: Own compilation of data based on EC n.d., and EEA (2021).

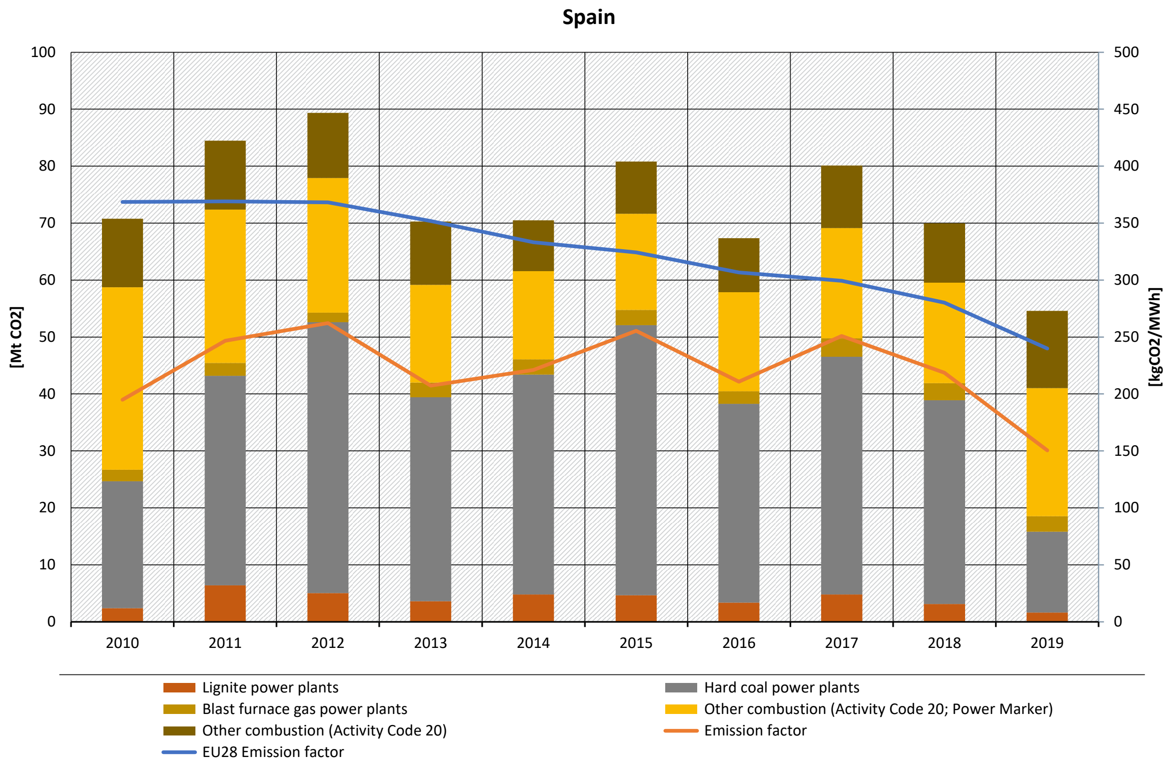
Figure 78 takes a closer look at combustion emissions disaggregated by fuel for the period 2010 to 2019. CO_2 emissions from hard coal power plants dominated the development of combustion emissions. They increased from 22 Mt CO_2 in 2010 to 48 Mt CO_2 in 2012, then fluctuated between 35 and 47 Mt CO_2 in the following years before dropping significantly to only 14 Mt CO_2 in 2019.

Lignite power plants showed strongly fluctuating emissions in the period considered: as they ranged between less than 2 Mt CO_2 (2019) and 6 Mt CO_2 (2011).

CO_2 emissions from blast furnace gas power plants ranged between 2 Mt CO_2 and 3 Mt CO_2

Emissions from other power plants (mainly natural gas) decreased from 32 Mt CO_2 in 2010 to 15 Mt CO_2 in 2014. They increased again in the following years and reached 23 Mt CO_2 in 2019.

Figure 78: Spain: Emission trends from combustion installations in Activity Code 20



Note: Emissions in the category: other combustion (Activity Code 20; Power Marker) are calculated using the deduction method: All emissions with Power Marker minus emissions from lignite and hard coal-fired power plants minus emissions from blast furnace gas power plants.
Source: Own illustration based on data from Europe Beyond Coal (2022), EEA (2021), Ember (2020), and own assignment based on EC n.d..

The emission intensity of gross electricity generation in Spain shows substantial fluctuations between 200 kg CO_2/MWh and 260 kg CO_2/MWh in the years 2010 to 2018, depending on the share of hard coal emissions compensating for lower levels of hydro power. The Spanish emission intensity was lower than the EU-28 average during the whole period and dropped to a minimum of 150 kg CO_2/MWh in 2019.

11.3 Capacity trends

11.3.1 Existing capacities

Figure 79 shows the development of the installed capacity of power plants in Spain[13] from 2006 to 2019.

The capacity of hard coal-fired power plants decreased from 12 GW in 2006 to 9 GW in 2019.

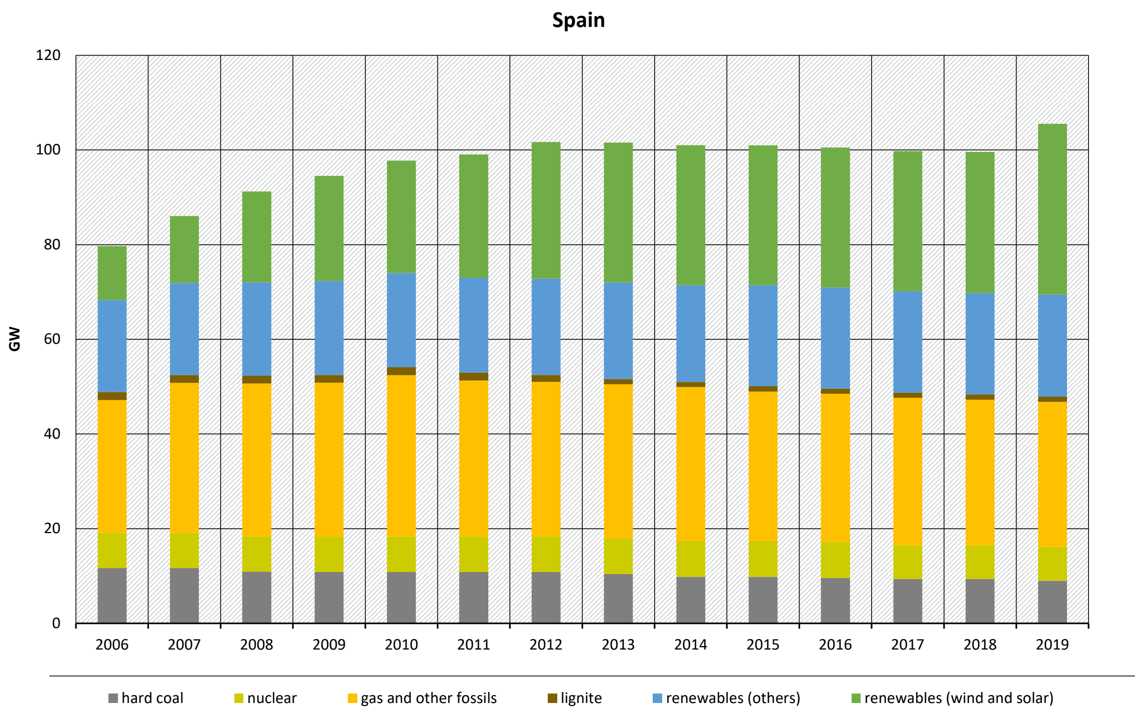
The last lignite-fired power plant was closed in 2020. Previously, Spain had a small number of lignite-fired power plants with a total capacity of 1.7 GW in 2006, which decreased to 1.1 GW by 2019.

[13] Only power plants on the Spanish territory of the Iberian Peninsula.

The capacity of Spain's nuclear power fleet fell from about 7.5 GW in 2006 to about 7.1 GW in 2019 due to the closure of a 0.5 GW unit at the end of 2012. Today, Spain operates seven nuclear reactors at five sites.

The category "gas and other fossils" in Figure 79 includes a large amount of gas-fired power plants including power plants labelled as "co-generation" with no specific fuel information in the statistics of the Spanish grid operator RED (RED Electrica de Espana 2006-2014; 2015-2019). The installed capacity of this category ranged between 28 GW in 2006 and 34 GW in 2010 with a slight decline to 31 GW in 2019.

Figure 79: Spain: Evolution of capacity trends by energy carrier



Source: Own illustration based on data from RED Electrica de Espana (2015-2019), RED Electrica de Espana (2006-2014), Europe Beyond Coal (2022).

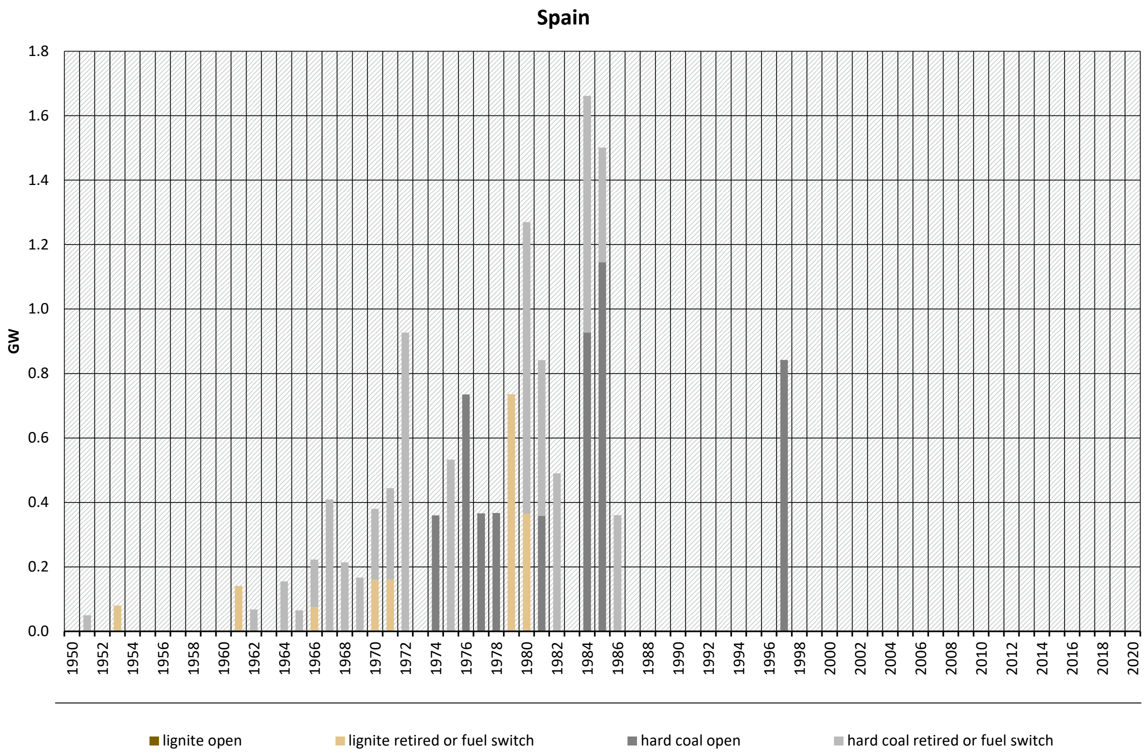
Spain has considerable renewable energy capacities. The renewable capacity of wind and solar (including photovoltaics and solar thermal) plants increased from 11 GW in 2006 to 36 GW in 2019. While there was a strong increase in photovoltaics from 2006 to 2012 (from 0.1 GW to 4.3 GW), the construction of new PV plants stagnated from 2013 onwards. It was only from 2018 to 2019 that there was a large addition of new capacities again, which almost led to a doubling of the installed PV capacity (from 4.5 to 8.5 GW). Capacities of other renewable energy sources are dominated by hydro power and increased from 19 GW in 2006 to 22 GW in 2019.

The comparison between Figure 78 and Figure 79 shows the dominant role of coal-fired power plants in CO_2 emissions. Figure 80 thus takes a closer look at the hard coal power plants in Spain by detailing their age structure. The graph includes coal plants that are retired by now in a paler shade. The following can be observed:

- Between 1961 and 1986 new coal-fired power plants were commissioned almost every year except in 1973 and 1983. These were mostly hard coal-fired power plants.

- The hard coal power plants commissioned between 1962 and 1972 (12 blocks with almost 2.7 GW total) were all retired between 2007 and 2020.
- The hard coal power plants commissioned between 1974 and 1986 had a capacity of 8.1 GW (21 blocks), 10 blocks with 3.3 GW of which were retired between 2018 and 2020. A 500 MW unit from 1975 was already decommissioned in 2007.
- The most recent addition to the coal-fired power plant fleet are three units from 1997 that belong to Endesa: two 130 MW units at the Alcudia II site and one 580 MW unit at the Litoral site.
- All lignite-fired power plants, including the most recent from 1979/80, had been shut down by 2020 at the latest.

Figure 80: Spain: Age structure of lignite and hard coal power plants sorted by year of commissioning

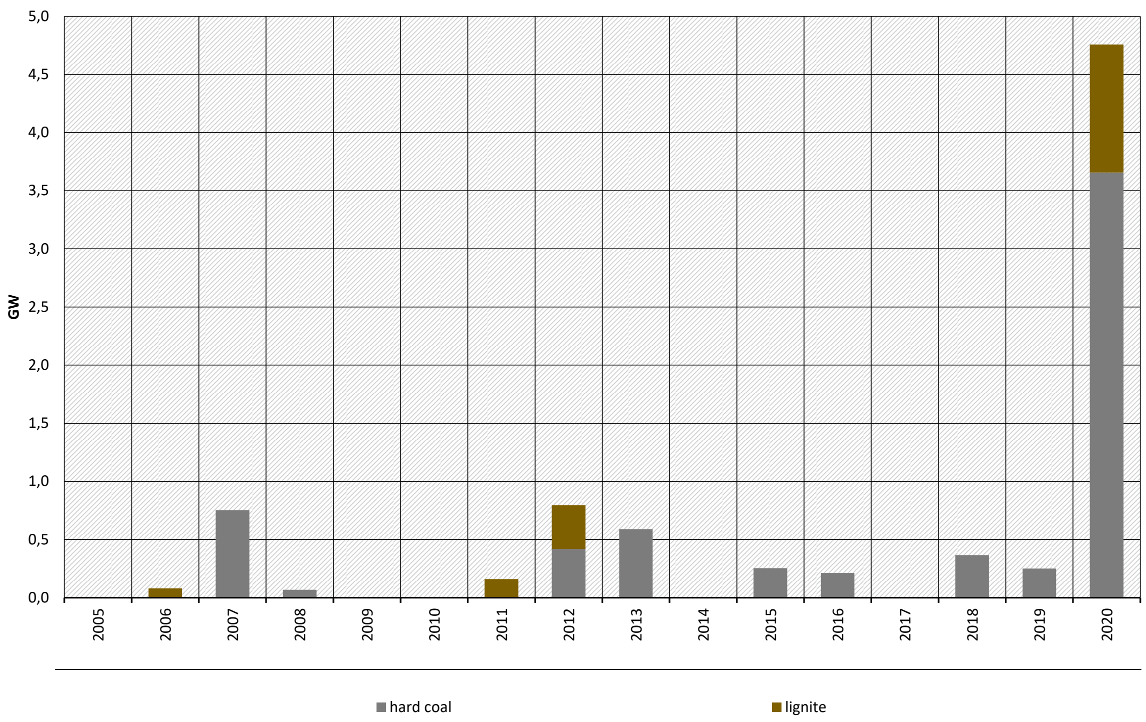


Source: Own illustration based on data from Europe Beyond Coal (2022).

Coal-fired power plants were decommissioned between 2006 and 2020 (see Figure 81). Nine lignite-fired units with a total capacity of 1.7 GW were retired during this period, including three 370 MW units at the Teruel power station, which were commissioned in 1979/80 and shut down in 2020.

24 hard coal-fired units with a total capacity of almost 6.6 GW and commissioning dates between 1951 and 1986 were also decommissioned, 11 of which in 2020 alone (a total of 3.6 GW).

Figure 81: Spain: Retired coal-fired plant capacities sorted by retirement date



Source: Own illustration based on data from Europe Beyond Coal (2022).

11.3.2 Future capacity trends

Conventional power plants

The Spanish NECP (Government of Spain 2020) entails a coal phase-out in the electricity sector by 2030 at the latest due to economic pressure from the EU ETS. The reduction of coal-fired power plant capacity is already underway, with the closure of seven power plants (hard coal and lignite) with a total capacity of almost 4.8 GW in 2020, leaving only 5 GW in operation.

Spain's seven nuclear reactors all started operation in the 1980s. In 2019, the government decided to close the seven nuclear reactors step-by-step between 2025 and 2035 (Magnus commodities 2019). This means a lifetime extension beyond the 40-year limit that had applied until the government lifted it in 2011. There are no plans for new nuclear power plants in Spain (Planelles 2021).

Mining areas

There was lignite mining in Spain; in 2007, however, the last Spanish lignite mines in Galicia were closed. The Teruel power plant, classified as burning lignite, gradually switched to higher range coal from the region and to imported hard coal.

After a so-called "Just Transition" plan was developed with the trade unions and after a history of economic pressure on the subsidised mines all hard coal mines in Spain were closed by December 2018 (except for the San Nicolas mine in Mieres, a town in Asturias) (Euracoal 2020).

Targets for power generation based on renewable energies

The Spanish NECP (Government of Spain 2020) targets at a 74 % share of renewable energy in electricity generation by 2030. This is to be accomplished by achieving a total of 50 GW of wind energy, 39 GW of solar photovoltaic, 7 GW solar thermal electric, 16 GW hydroelectric energy and about 2 GW of other renewable sources including biomass. Almost 270 TWh of renewable electricity are thereby generated.

Spain's support for renewable electricity was initially a feed-in tariff ("Régimen Especial") that applied until the end of 2011 and was suspended at the beginning of 2012 (RES LEGAL Europe 2019e). The reason for this was that a deficit for refinancing had occurred due to high tariff costs and high installation numbers, especially for photovoltaics. After all support for new installations was frozen in 2012, a new decree of July 2013 updated the support scheme by replacing the previous feed-in tariff with two types of remuneration ("Régimen Retributivo Específico"). The first is a price per unit of installed capacity (€/MW), which covers the investment costs that cannot be covered by the sale of electricity, and the second is an operation-related price (€/MWh), which covers the difference between the operating costs and the revenues from the market participation of plants, where appropriate (CMS 2020c). The amount of these remunerations is calculated for the configuration of defined standard plants. In 2016 and 2017, three competitive auctions for 8.7 GW of renewable capacity were launched under this support scheme and fully subscribed, resulting in the construction of mainly wind and PV installations from 2018 to 2020 (The Law Reviews 2021).

The NECP also sees auctions as the most important policy instrument for the expansion of renewable energies. In order to achieve the NECP targets, Spain has introduced a new support system that led to a first auction for renewable energy being organized in January 2021. The new support scheme ("Régimen Económico de Energías Renovables") replaces the previous one and provides for further auction rounds until 2025 (del Río and Menzies 2021).

11.3.3 Ownership structure of coal power plants

Table 37 shows the ownership structure of the operational hard coal-fired power stations in Spain. Endesa owns 8 blocks at three sites with a total capacity of 2.9 GW, comprising 57 % of the hard coal-fired capacity. Number two is EDP España with three blocks with a total capacity of 1.3 GW or 25 % of the hard coal-fired capacity. Viesgo and Iberdrola each own one unit.

Table 37: Spain: Ownership structure of the coal-fired electricity generation fleet

Owner	Gross generation capacity [MW]	Company's share of total coal capacity	
	hard coal	share %	cum. Share %
Endesa	2888	57%	57%
EDP España	1266	25%	81%
Viesgo	589	12%	93%
Iberdrola	358	7%	100%

Source: Own table based on Europe Beyond Coal (2022).

11.4 Trends in electricity generation and import balance

Figure 82 shows the gross electricity generation and gross consumption as well as the net imports of electricity in Spain broken down by energy carrier since 2005.

Consumption has fallen since 2005. From 2005 to 2008, consumption amounted to around 300 TWh with a slightly increasing trend. It dropped to less than 290 TWh in 2009, decreased to 275 TWh in 2014 and has amounted to between 280 and 285 TWh since then.

The contribution of **nuclear** power plants to electricity generation was between 53 TWh and 62 TWh during the whole period.

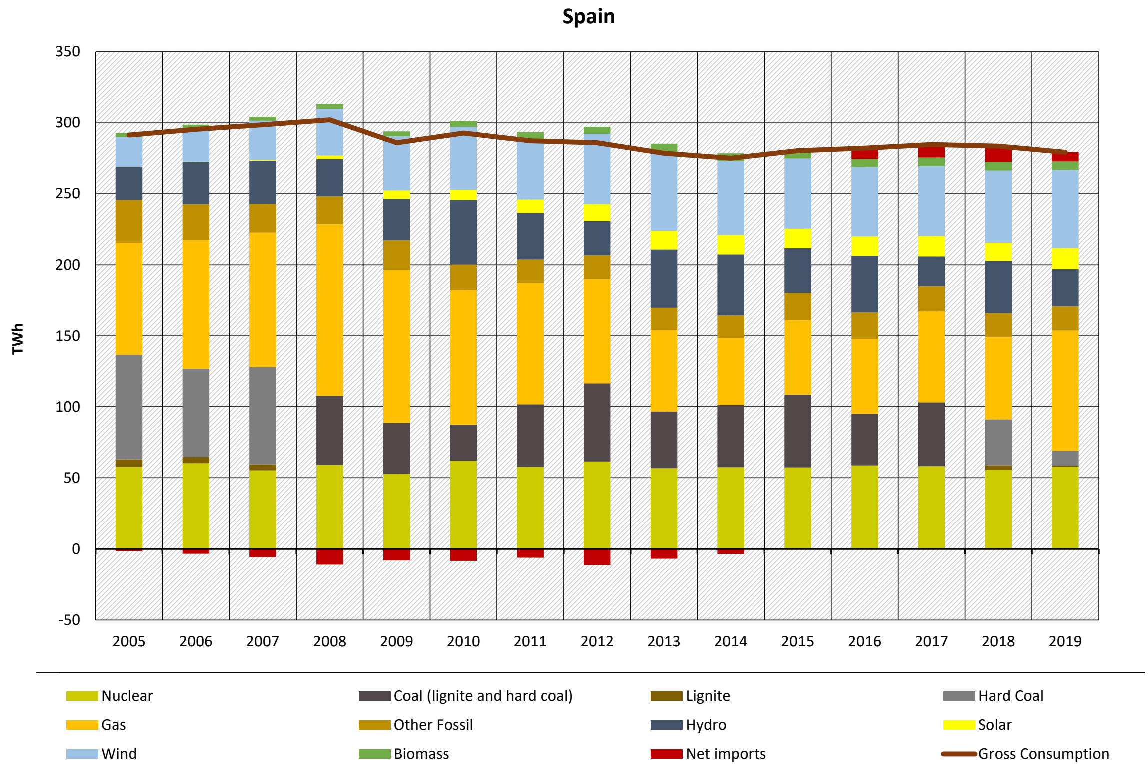
Lignite-fired power plants produced 4 TWh – 5 TWh from 2005 to 2007. Data for electricity generation from lignite are not available for the years 2008 to 2017 and are included in the data for coal in Figure 82. In 2018, lignite-fired power plants produced 3 TWh. In 2019, only 0.5 TWh were generated from lignite before the last lignite power plant was closed in 2020.

Hard coal-based generation has declined significantly. In the years 2005 to 2007, electricity generation from hard coal still amounted to between 62 TWh and 74 TWh. Data for coal (both lignite and hard coal) showed strong fluctuations from 2008 to 2017, with values between 25 TWh and 55 TWh. Hard coal-based electricity generation then decreased strongly from 32 TWh in 2018 to 11 TWh in 2019.

Natural gas increased from about 80 to 120 TWh between 2005 and 2008. It then steadily decreased to below 50 TWh in 2014 which was the minimum of electricity production from natural gas in the period considered. With the decline of coal-based electricity production, natural gas power plants have increased their production in recent years again, reaching 85 TWh in 2019.

Other fossil electricity generation decreased from 30 TWh in 2005 to 17 TWh in 2019.

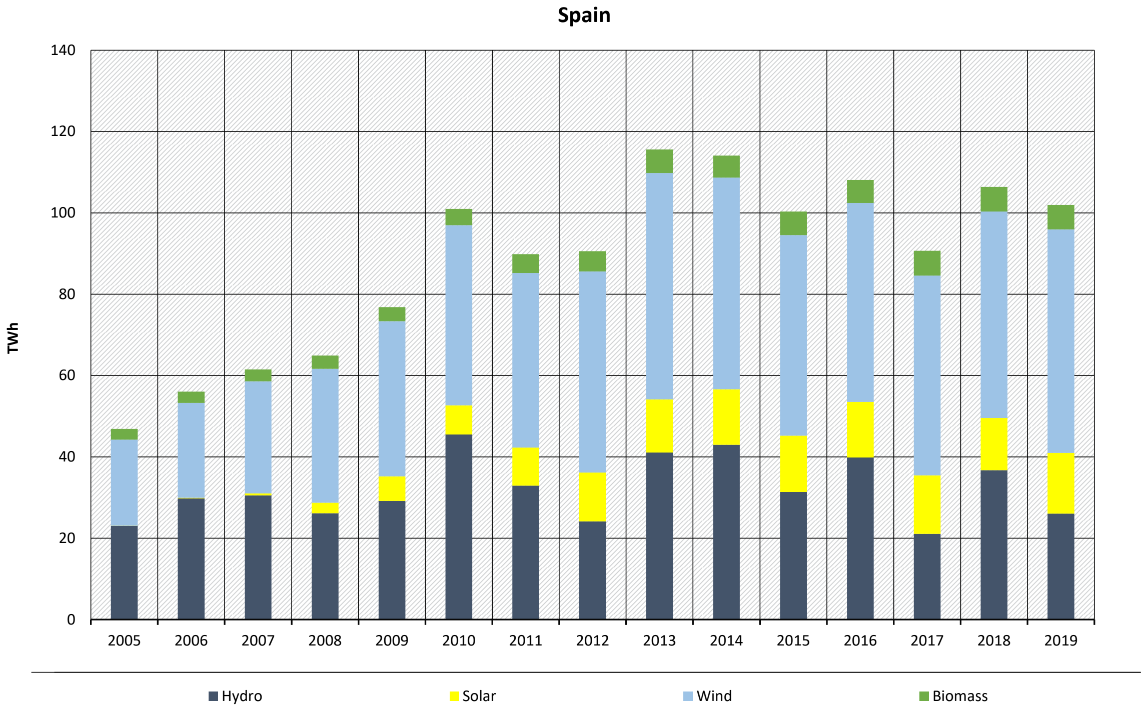
Figure 82: Spain: Trends of gross electricity generation and net imports



Source: Ember (2020).

Renewable energies (see Figure 83) have increased from less than 50 TWh in 2005 to 116 TWh in 2013. Between 2014 and 2019, electricity generation from renewables fluctuated between 91 and 114 TWh. Wind energy has contributed the largest amount of electricity; it increased from 21 TWh in 2005 to 56 TWh in 2013 and has fluctuated between 49 TWh and 55 TWh since 2014. Solar power has increased since 2007, reaching a level of 13 to 15 TWh between 2013 and 2019. Hydropower was subject to strong fluctuations in the period under consideration and contributed between 21 TWh and 46 TWh. Electricity from bioenergy plays a smaller role. It rose from 3 TWh in 2005 to about 6 TWh in 2013 and has remained constant since then.

Figure 83: Spain: Electricity generation of renewable energies

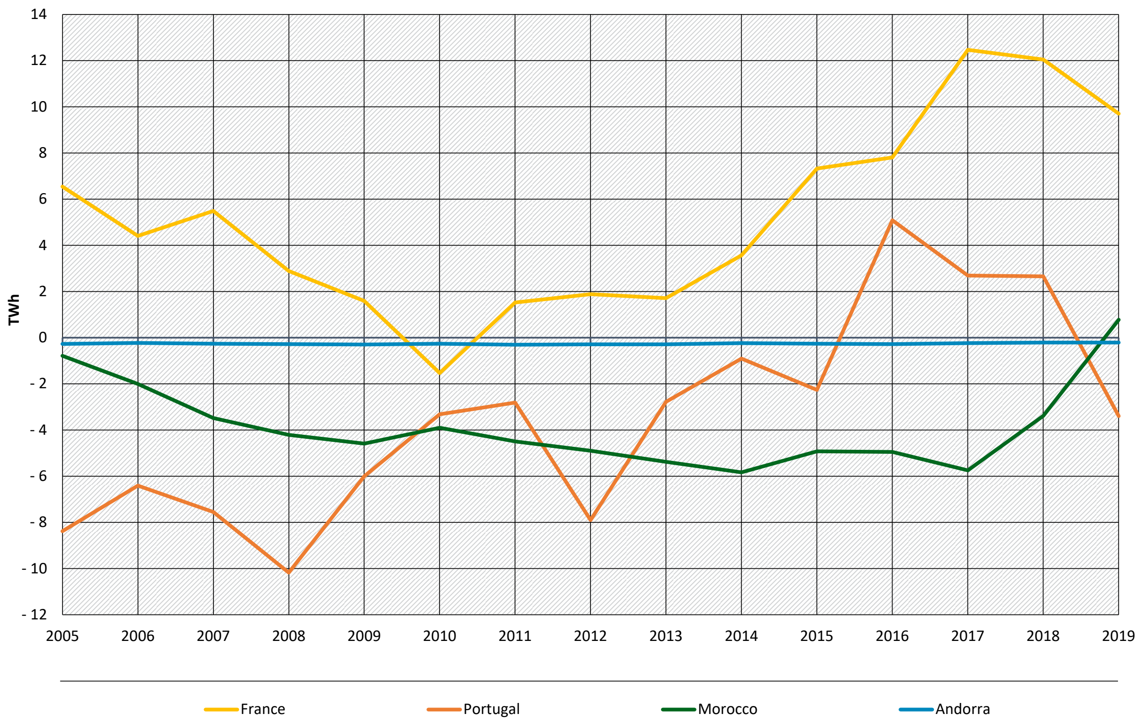


Source: Ember (2020).

Figure 84 shows the net electricity exchange between Spain and its neighbours between 2005 and 2020.

In all years considered except 2010, there were net imports from France to Spain. In 2017 and 2018, net imports increased up to 12 TWh; prior to that, they mostly amounted to between 2 TWh and 8 TWh. From 2005 to 2015, Spain was a net exporter to Portugal with yearly net exports ranging between 1 TWh and 10 TWh with a declining trend. This changed in 2015 when Spain imported electricity from Portugal until it returned to net exports in 2019. There were also net exports to Morocco, which amounted to between 1 TWh and 6 TWh in almost all years except 2019. Stable but small annual net exports of 0.3 TWh go to Andorra.

Figure 84: Spain: Net import (positive) and net export (negative) of electricity, physical exchange with neighbouring countries



Source: RED Electrica de Espana (2005-2019).

11.5 Market setting

11.5.1 Regional market allocation and interconnectors

The only designated NEMO in Spain is called OMIE S.A. It manages the day-ahead and intraday electricity markets on the Iberian Peninsula.

Spain and Portugal joined the North-Western Europe (NWE) market coupling project in May 2014, which covered most of Western Europe at that time.

Table 38 shows the maximum forecasted transfer capacities between Spain and its neighbours France and Portugal according to ENTSO-E data and to Morocco based on data from RED.

Table 38: Spain: Maximum forecasted transfer capacity with neighbouring countries in 2021 (MW)

		FR	PT	MAR[1]
ES	to	2800	2700	900
ES	from	3000	2790	600

Note: [1] Values for Morocco are based on data from REE (2022).

Source: Own data based on ENTSO-E.

11.5.2 Electricity market design with reference to conventional power generation plants

In 2021, the Spanish government started a consultation process on the introduction of a capacity market in the electricity sector. The proposal suggests a centralized system through which the TSO, Red Eléctrica de España, S.A., will contract the capacity needs (in MW) determined in a demand coverage analysis. The contracted capacity must ensure its availability at the times of greatest stress for the mainland electricity system and will be contracted through competitive procedures (pay-as-bid auctions) managed by the TSO.

The regulation envisages two types of auctions: main auctions with a capacity service provision period starting within a period of maximum five years from the award and adjustment auctions with a 12-month capacity service provision period starting within a period of maximum 12 months from the award. The main auctions are intended to guarantee the capacity needs of the mainland electricity system, while at the same time encouraging investment in manageable assets such as storage. The adjustment auctions are intended to resolve any possible coverage problems that will not be solved through the capacity guaranteed by means of the main capacity auctions.

In addition, and as provided for in article 22 of Regulation (EU) 2019/943, an emission limit of 550 g CO_2/kWh is generally established for existing generation facilities participating in the mechanism, while new investments geared to participating in the mechanism must prove that they correspond to non-emitting facilities.

The introduction of a capacity market is motivated by the increasing share of fluctuating renewable energy sources. It is also intended that the capacity market contributes to the installation of a total of 20 GW of storage capacity by 2030 (MITECO 2021).

12 United Kingdom

12.1 Key messages

- In 2019, combustion installations (Activity Code 20) in the United Kingdom emitted 81 Mt CO_2, which made it the 4th largest emitter (9 %) in this category. Electricity producers account for only 59 % of emissions under this category. Between 2013 and 2019, emissions from electricity generators decreased by 67 %.
- The United Kingdom generation mix is dominated by gas-fired generation which accounted for 40 % of generation in 2019, up from 27 % in 2013. Hard coal contributed a share of 2 % in 2019, while in 2013 generation amounted to 130 TWh or 18 times higher. Due to stronger EU air quality regulations and the introduction of a carbon floor price in 2013, many coal-fired units were retired instead of retrofitting them or were converted to biomass-firing. The entire remaining coal-fired generation fleet was installed before 1990. Nuclear power provides about 20 % of total production.
- Electricity supply from renewables comprised 38 % of total generation in 2019, which constitutes an increase of 143 % since 2013. A rapid expansion of wind and solar capacities started in 2011; biomass-based generation has expanded since 2013.
- The emission factor of gross electricity production, at 0.15 t CO_2 per MWh, is approx. 40 % lower than the value for the EU-28 in 2019. With decreasing coal-fired generation and increasing RES-E supply, it has decreased by 64 % since 2013.
- The United Kingdom is a major importer of electricity in the European electricity system. Imports originating from France, the Netherlands and Belgium comprise 6 % of gross electricity consumption. A new interconnector with Norway started trial trading in October 2021.
- A coal phase-out is planned for late 2024. In parallel, the 3.3 GW nuclear power plant Hinkley Point C is under construction. After several delays, the first block is scheduled to go online in 2031. The power plant is financed through a flexible market premium (contract for difference).

Table 39 United Kingdom: Key figures on the electricity sector in 2019

	2019	% change compared to 2013
	CO_2 emissions	
Total CO_2 emissions in 2019 from ETS Activity Code 20 (share of EU-28)	81 Mt CO_2 (9%)	-54%
Total CO_2 emissions from electricity producers[1] (share of combustion installations in the country)	48 Mt CO_2 (59%)	-67%
Emission factor of gross electricity production[2] (relative to EU-28 average)	0.15 t CO_2/MWh (63%)	-64%
	Gross electricity generation	
Total (share of total EU-28)	322 TWh (10%)	-10%
Net electricity imports	22 TWh	53%
Lignite share in gross generation (share of total gross lignite-fired generation in EU-28)	0% (0%)	0%
Hard coal share in gross generation (share of total gross hard coal-fired generation in EU-28)	2% (3%)	-94%
RES share in gross generation (target for 2030)[3]	38% (50% - 75%)	143%
	Installed capacity	
Total lignite-fired capacity installed (share of total EU-28)	0 GW (0%)	0%
Share of lignite-fired capacity installed before 1990 (share of total EU-28)	0%	0%
Total hard coal-fired capacity installed (share of total EU-28)	12.4 GW (13%)	-55%
Share of hard coal-fired capacity installed before 1990 (share of total EU-28)	100% (12%)	0%

Note: [1] CO_2 emissions from electricity producers based on power plants identified in Oeko-Institut's EU ETS database.
[2] Emission factor calculated based on CO_2 emissions by power plants identified in Oeko-Institut's EU ETS database and gross electricity production reported by Ember (2020) .
[3] According to Article 4 (2) Regulation (EU) 2018/1999, MSs have to provide information on their contribution to the Union's binding renewable energy target of at least 32% expressed as renewable energy share on gross final energy consumption. They do so in their NECPs (Article 3(2)(b)). Along with this contribution they also have to report on *estimated trajectories for the sectoral share of renewable energy in final energy consumption from 2021 to 2030 in the electricity, heating and cooling, and transport sector* (see Annex I Regulation (EU) 2018/1999 which sets out the structure of the NECPs)
Source: Own table based on Ember (2020), EC n.d., Europe Beyond Coal (2022), and EEA (2021).

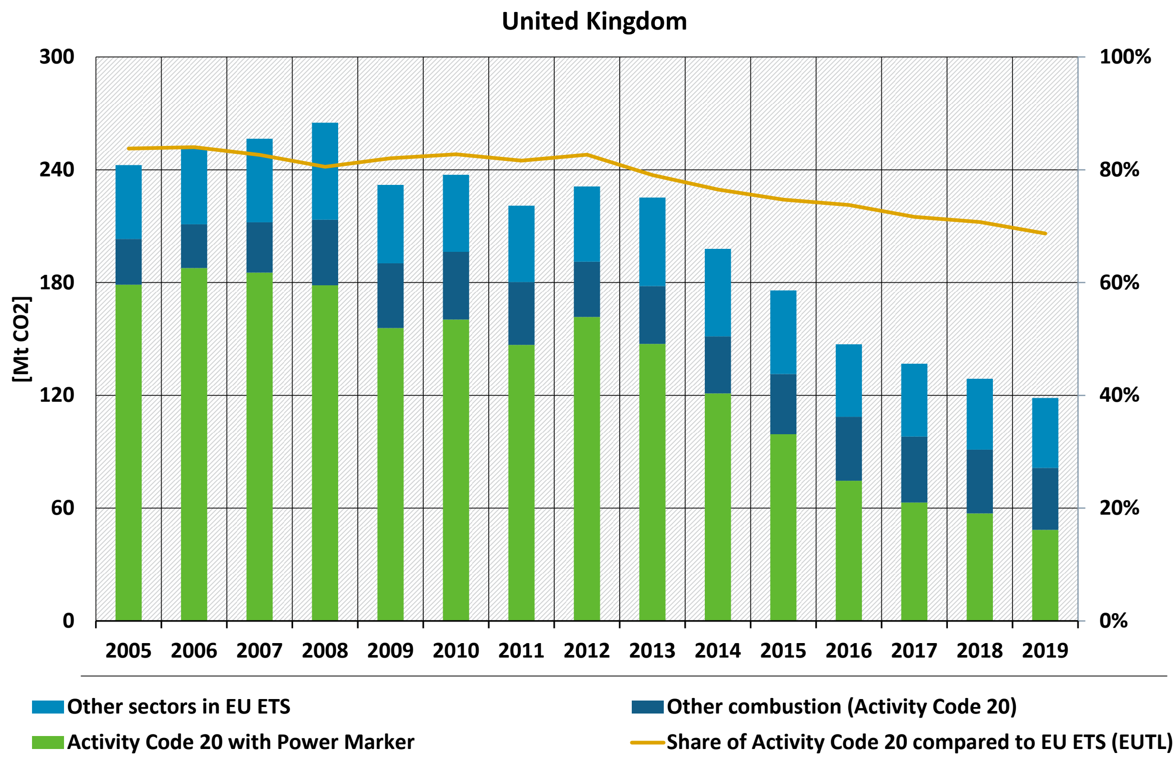
12.2 Emission trends in the EU ETS (combustion installations)

Figure 85 shows CO_2 emissions under the EU ETS in the UK from 2005 to 2019. CO_2 emissions from combustion installations accounted for between 69 % and 84 % of total emissions.

After ETS emissions increased from about 240 Mt to 265 Mt between 2005 and 2008, they dropped to a level of approx. 230 Mt CO_2 between 2009 and 2013 and then continuously declined to 120 Mt CO_2 in 2019.

CO_2 emissions from combustion installations (Activity Code 20) decreased even more strongly (minus 60 % from approx. 200 Mt CO_2 in 2005 to 80 Mt CO_2 in 2019).

Figure 85: United Kingdom: Emission trends in the EU ETS



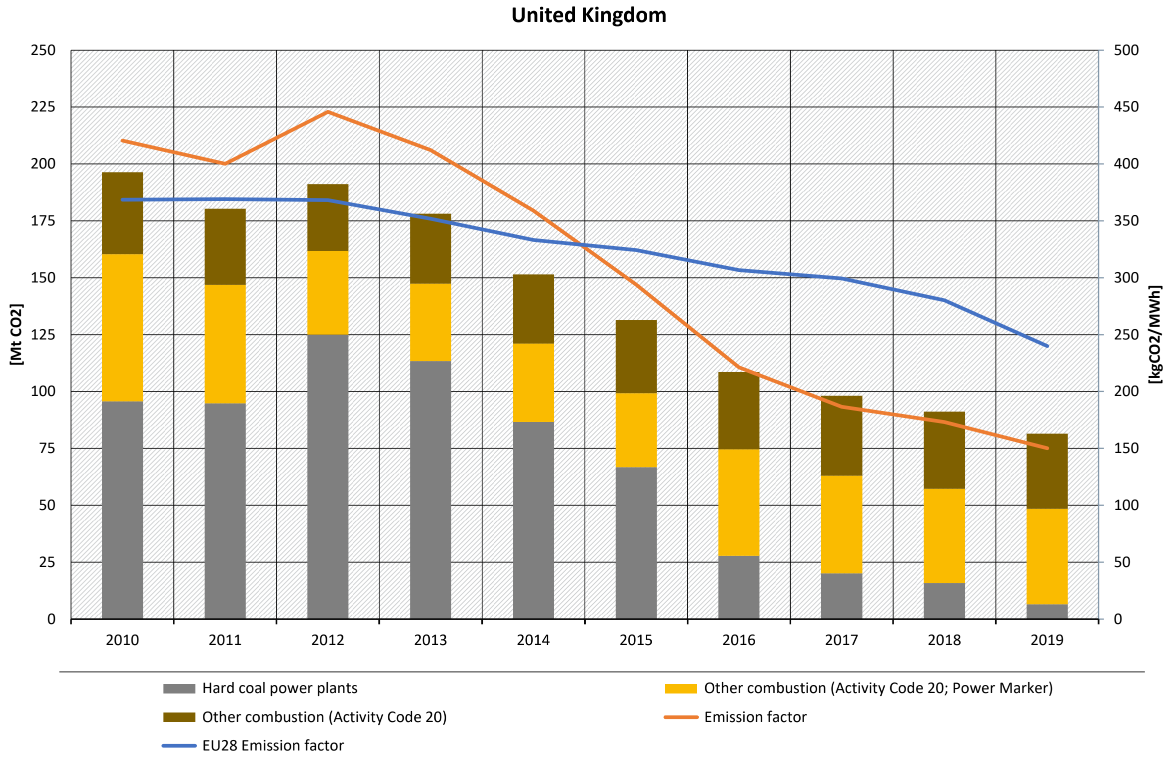
Source: Own compilation of data based on EC n.d., and EEA (2021).

Figure 86 shows the reason for this strong decrease: It details the combustion emissions by fuel. Between 2010 and 2019, CO_2 emissions from hard coal power plants were reduced from 125 Mt CO_2 in 2012 to 6 Mt CO_2 in 2019 as a result of the UK coal phase-out (see 0).

Emissions from other fossil power plants decreased from 65 Mt CO_2 in 2010 to 42 Mt in 2019. Other combustion than power generation accounted for emissions between 29 Mt CO_2 and 36 Mt CO_2 with no clear trend over time.

Figure 86 also shows that the UK's emission factor has declined much more sharply than the emission factor of the EU-28 average. In 2012, the UK's emission factor was 464 kg CO_2/MWh, 1.2 times higher than the European one. In 2019 it was only 150 kg CO_2/MWh, which corresponds to only 63 % of the EU-28 value.

Figure 86: United Kingdom: Emission trends in Activity Code 20



Note: Emissions in the category: other combustion (Activity Code 20; Power Marker) are calculated using the deduction method: All emissions with Power Marker minus emissions from lignite and hard coal-fired power plants minus emissions from blast furnace gas power plants.
Source: Own illustration based on data from Europe Beyond Coal (2022), EEA (2021), Ember (2020), and own assignment based on EC n.d..

12.3 Capacity trends

12.3.1 Existing capacities

Figure 87 shows the development of the installed capacity of power plants in the United Kingdom from 2005 to 2020.

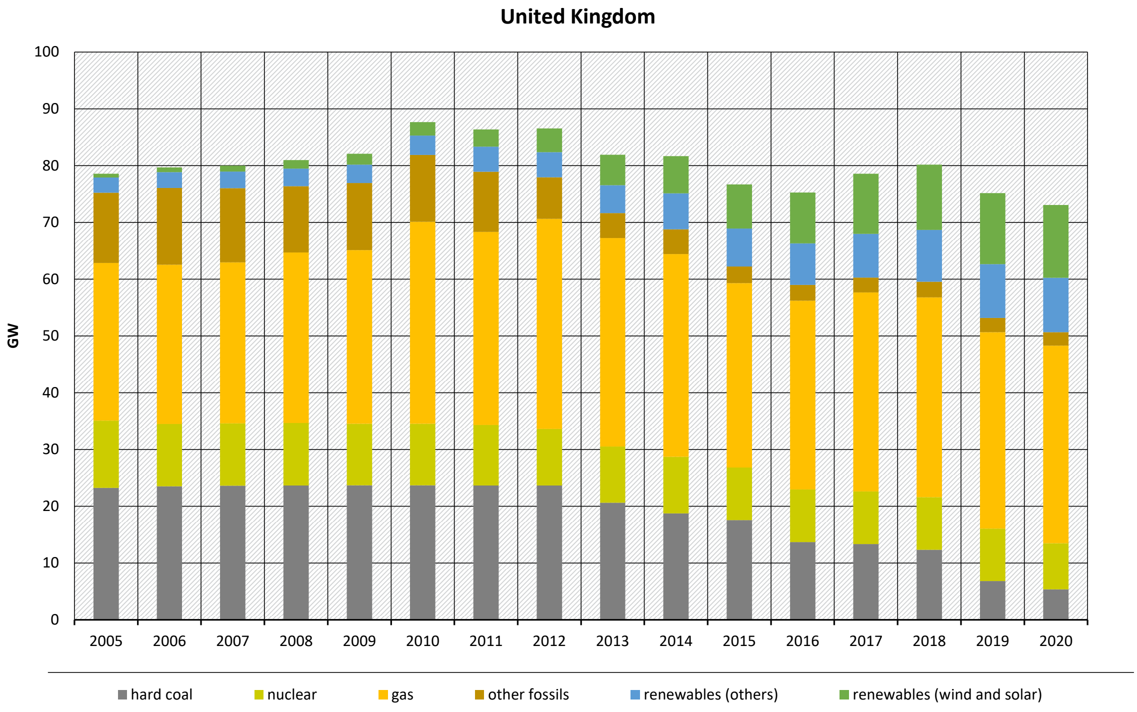
The capacity of hard coal-fired power plants amounted to almost 24 GW until 2012. It halved to 12 GW by 2018 and more than halved again to just over 5 GW in 2020 due to the UK's coal phase-out policy.

In 2020, the capacity of nuclear power plants was 8 GW, a decrease from 12 GW in 2005 due to the closure of four units and the change in output of some others.

Gas-fired power plants have the largest share and have increased their capacity from 28 GW in 2005 to 35 GW in 2020.

The capacity of other fossil-fired power plants fell from about 12 GW between 2005 and 2011 to only 2 GW in 2020.

Figure 87: United Kingdom: Evolution of capacity trends by energy carrier



Source: Department for Business, Energy & Industrial Strategy (2021b).

The renewable capacity of wind and solar plants increased from less than 1 GW to 13 GW in 2020.

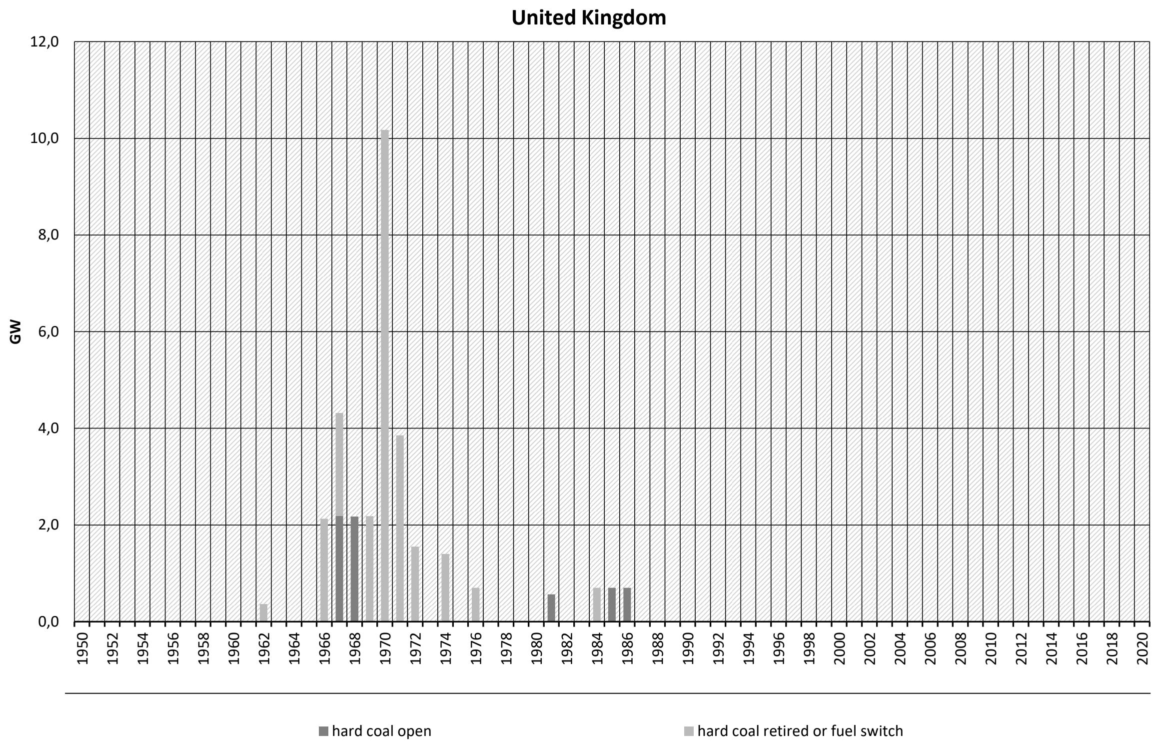
The other renewable category in Figure 87 includes hydropower plants as well as biomass-fired plants (including biogenic waste). In 2005, the capacity of such plants was less than 3 GW ; their capacity had increased to almost 10 GW in 2020. This increase is due to additional biomass and waste capacity, which has increased from 1.3 GW in 2005 to almost 8 GW in 2020. Part of this increase is due to the conversion of formerly coal-fired to biomass-fired plants. The most prominent example of such a conversion is the Drax power plant, in which biomass units comprised a capacity of 2.6 GW in 2020.

The comparison between Figure 86 and Figure 87 shows the dominant role of coal-fired power plants for CO_2 emissions in the UK. Figure 88 therefore takes a closer look at the hard coal power plants in the UK by detailing their age structure. The graph includes coal plants that are retired or switched to other fuels by now in a paler shade. The following can be observed:

- From the mid-1960s to the mid-1970s, there was a strong first wave of investment: Almost the entire hard coal capacity was installed during these years. In 1970 alone, more than 10 GW were installed. 59 units with a total capacity of almost 29 GW were built within 10 years, including many small units of less than 200 MW.
- In the 1980s, five more units were added with a total capacity of 2.7 GW. No more hard coal-fired power plants were subsequently installed in the UK.

Most of the capacity has been shut down in the meantime. The remaining 12 blocks are located in four sites: four blocks in Ratcliffe (2.2 GW), four in West Burton (2.2 GW), two in Drax (1.4 GW) and two in Kilroot (0.6 GW).[14]

Figure 88: United Kingdom: Age structure of hard coal power plants sorted by year of commissioning

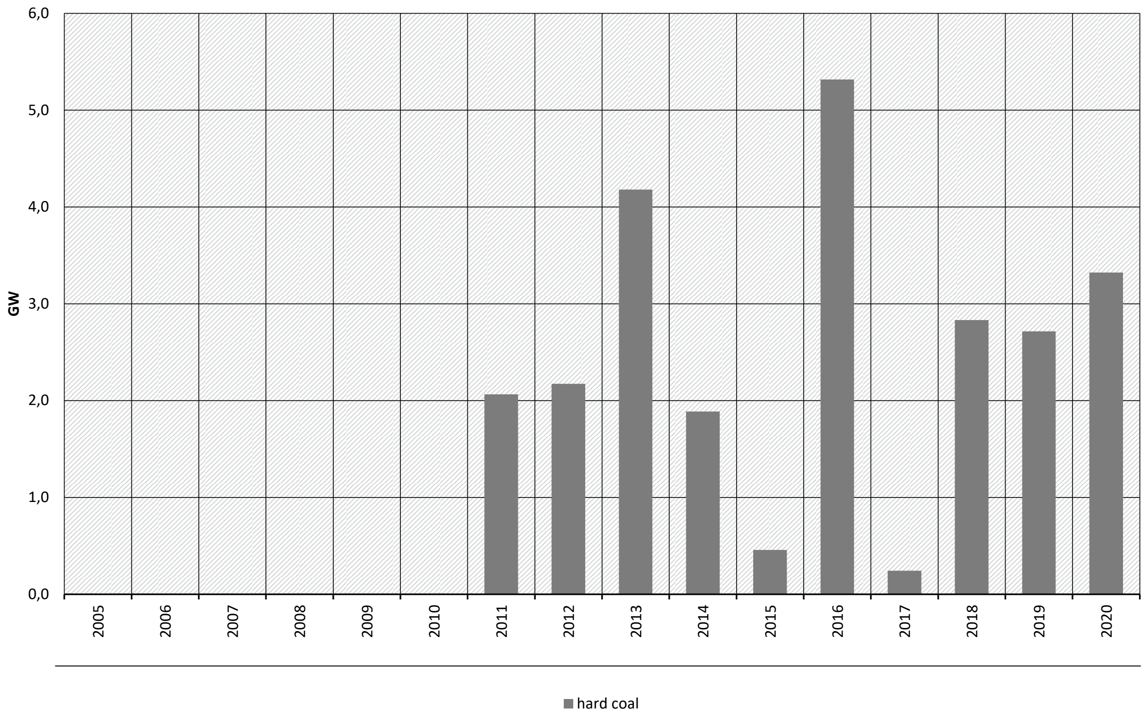


Source: Own illustration based on data from Europe Beyond Coal (2022).

Figure 89 shows the most recent closures of hard coal-fired power plants in the UK, organized by closure date. Between 2011 and 2020, 52 units with a total capacity of 25.2 GW were decommissioned or converted (partly temporarily) to biomass firing. The latter applies to 12 units at the four power plant sites Drax, Lynemouth, Tilbury (conversion to biomass) and Uskmouth (conversion to waste firing) with a total capacity of almost 4.5 GW. Ironbridge and Tilbury, however, experienced substantial fires due to the volatility of biomass material and subsequently closed the plants (Littlecott et al. 2018).

[14] The values are taken from Ember's coal data base ((Europe Beyond Coal 2022)). The capacity for power plants is given with lower values in the DUKES statistics (Department for Business, Energy & Industrial Strategy 2021b) compared to Ember's more disaggregated data for single blocks used for the age structure data. One possible explanation could be the use of net and gross values for capacity.

Figure 89: United Kingdom: Retired coal-fired plant capacities sorted by retirement date



Source: Own illustration based on data from Europe Beyond Coal (2022).

12.3.2 Future capacity trends

Conventional power plants

In 2017, the UK government decided to phase out coal by October 2025. In summer 2021, this date was brought forward to October 2024 (Department for Business, Energy & Industrial Strategy 2021c). The decision to end coal-fired power generation completely was preceded by a policy that made the operation of coal-fired power plants less economical: as early as 2013, the UK introduced a carbon price floor (Grantham Research Institute on Climate Change and the Environment 2019).

Hinkley Point C is the first new nuclear power station to be built in the UK in over 20 years and is currently under construction. The two blocks will have a capacity of 3260 MW. After several delays, the first block is scheduled to go online in 2031 (EDF Energy 2024). The power plant is being built with considerable state aid, so-called “contracts for difference”. The government sets a “strike price” that is valid for 35 years. If the market price for electricity falls below this level, the government makes up the difference. If the price is higher, the owners, EDF Energy and China General Nuclear Power, have to pay back the difference (Haves 2021).

Besides the Hinkley Point plant, the UK is also interested in the new small nuclear reactor (SMR) concept. In November 2021 the government announced funding amounting to the equivalent of approximately 250 million Euro for the further development of SMR designs to be used in the UK (Department for Business, Energy & Industrial Strategy 2021e).

Mining areas

Though lignite reserves exist, mainly in Northern Ireland, only hard coal is mined in the UK (Euracoal 2020). Hard coal reserves were reported by Euracoal at 377 Mt for 2018, of which 33 Mt are in operational and permitted mines and 344 Mt in planned mines. The annual output in 2018 amounted to 2.6 Mt. In addition, 10.1 Mt were imported. Coal-based electricity generation consumed 6.7 Mt in 2018. The iron and steel industry is another large consumer of hard coal. With the phase-out of coal-fired power generation, coal mining in the UK is under pressure.

Targets for power generation based on renewable energies

The UK NECP (Department for Business, Energy & Industrial Strategy 2020) indicated two possible paths for the share of renewables in the electricity mix, one with a 50 % share in 2030 and one with a 75 % share in 2030. However, the UK government has recently announced more ambitious targets: the power sector is to be completely decarbonized by 2035 through a mix of renewables, new nuclear power plants and gas with CCS according to the “Net Zero Strategy” (HM Government 2021) published in 2021. This includes 40 GW of offshore wind by 2030 instead of 30 GW announced in the NECP. However, this strategy leaves open exactly how much electricity will come from renewable energies and how much from nuclear energy and gas-fired power plants with CCS.

Until 2019, there were two support schemes for renewable electricity generation in the UK: the feed-in tariff for small installations with a capacity of up to 5 MW and the contracts for difference for powers plants with more than 5 MW (RES LEGAL Europe 2019f). The feed-in tariff ceased in April 2019, leaving contracts for difference as the sole and main instrument to support renewable electricity.

UK-based generators of renewable electricity who meet the requirements can apply for a CfD in an auction. Successful project developers enter into a private law contract with the Low Carbon Contracts Company (LCCC), a state-owned company. Developers receive a payment for the electricity they generate over a 15-year period, which corresponds to the difference between the strike price (an electricity price reflecting the cost of investing in a particular low-carbon technology) and the reference price (a measure of the average market price for electricity in the UK market) Department for Business, Energy & Industrial Strategy 2022.

12.3.3 Ownership structure of coal power plants

Table 40 shows the ownership structure of the four operational coal-fired power stations in the United Kingdom. EDF owns the West Burton power plant with four blocks, which comprises 35 % of the remaining coal fleet. The Ratcliffe power station, which is owned by Uniper, is just as large. The two Drax blocks belong to Drax Power plc and comprise 22 % of the capacity. EPH holds the smallest share with the site in Kilroot (9 %).

Table 40: United Kingdom: Ownership structure of the coal-fired electricity generation fleet

	Gross generation capacity [MW]	Company’s share of total coal capacity	
Owner	hard coal	share %	cumulative share %
EDF	2187	35%	35%
Uniper	2174	34%	69%

	Gross generation capacity [MW]	Company's share of total coal capacity	
Drax Power plc	1402	22%	91%
EPH	565	9%	100%

Source: Own table based on Europe Beyond Coal (2022).

12.4 Trends in electricity generation and import balance

Figure 90 shows the gross electricity generation and gross consumption as well as the net imports of electricity in the United Kingdom since 2005, broken down by energy carrier. Consumption has fallen since 2005. Three phases can be observed: from 2005 to 2008, consumption amounted to approx. 400 TWh; following a sharp drop in 2009 to 380 TWh, consumption fell further to around 370 TWh in 2013; after a further drop to below 360 TWh in 2014, it declined to 345 TWh in 2019.

The contribution of **nuclear** power plants to electricity generation fluctuated between approx. 50 and approx. 80 TWh. From 2015 to 2017, it amounted to approx. 70 TWh, and in 2019 only 56 TWh.

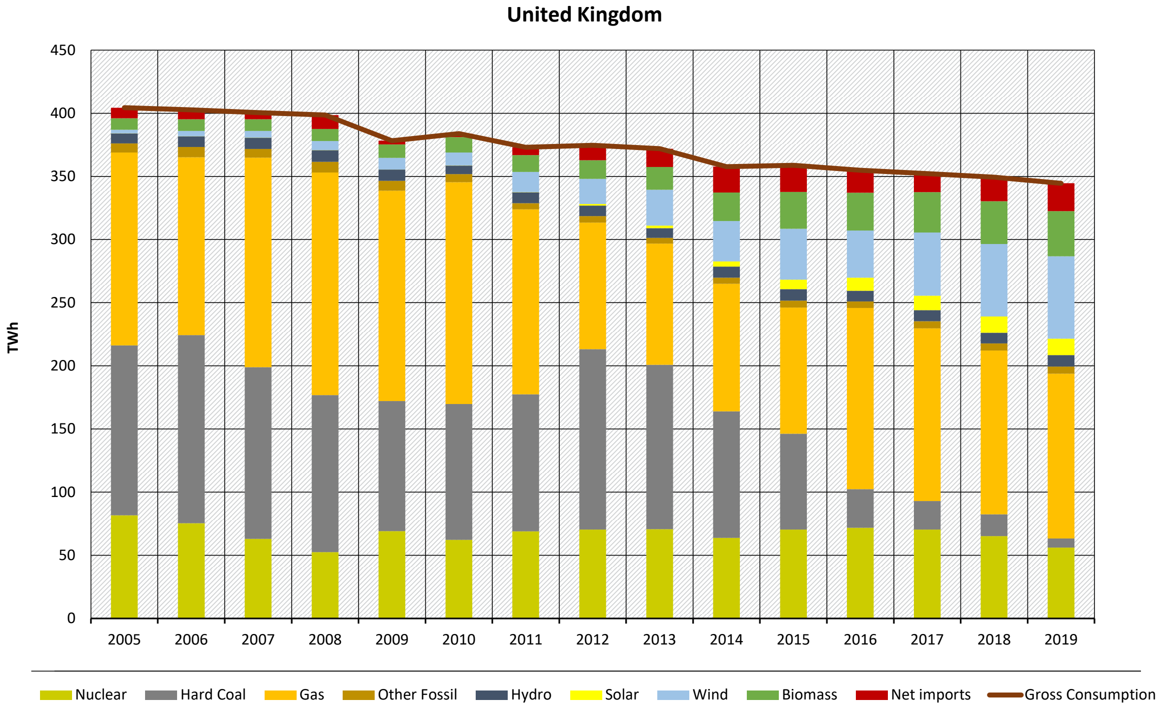
Hard coal-based generation has declined significantly. In the years 2005 to 2012, electricity generation from hard coal still amounted to between 103 and just under 150 TWh. In 2013, it fell to 130 TWh, in 2014 to 100 TWh, in 2015 to 76 TWh and in 2016 to 31 TWh. In 2019, the remaining hard coal power plants produced only 7 TWh.

Natural gas plays a major role in the UK electricity system. It is the energy source with the largest share of the electricity mix in 2019 contributing 130 TWh.

Historically, gas-fired electricity generation amounted to just over 150 TWh in 2005 and reached a maximum of 176 TWh in 2008 and 2010. In the years 2012 to 2015, electricity generation from natural gas fluctuated at around 100 TWh. In 2016, it rose to 143 TWh, replacing almost all coal-fired electricity.

Other fossil electricity generation was between 5 and 9 TWh in the period considered.

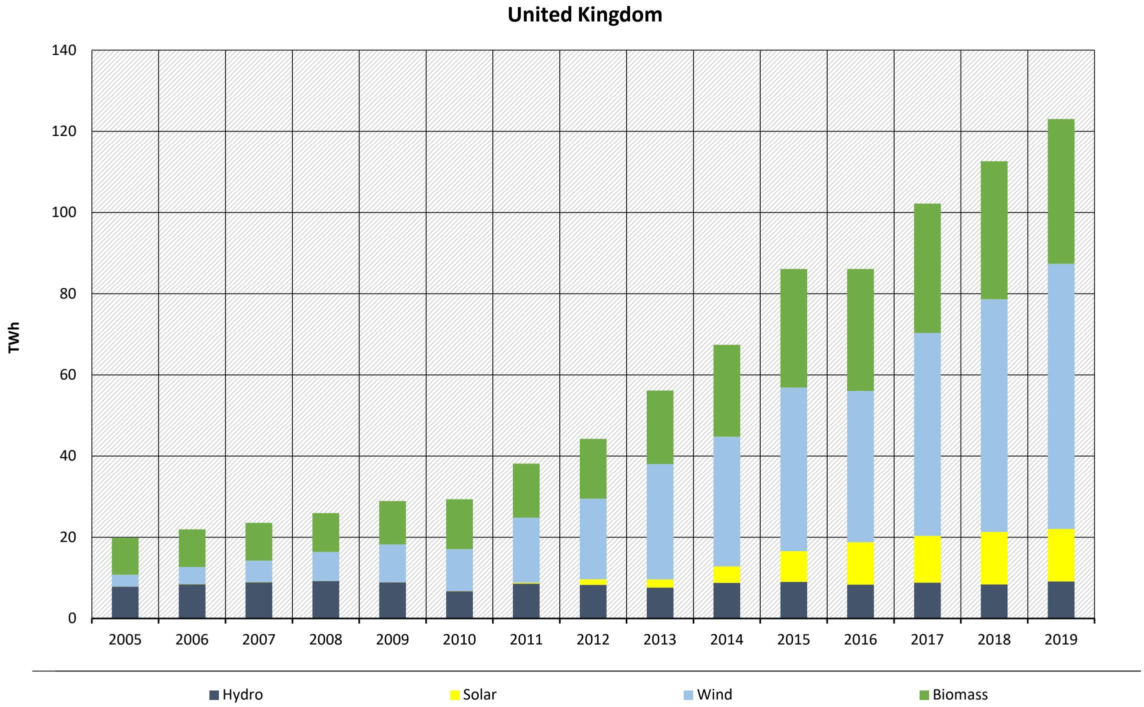
Figure 90: United Kingdom: Trends of gross electricity generation and net imports



Source: Ember (2020).

Renewable energies (see Figure 91) have increased from about 20 TWh in 2005 to more than 120 TWh in 2019. Hydro power plants contributed a constant baseline between 7 and 9 TWh. Due to the increasing conversion of coal-fired units to biomass, generation from biomass has increased from 9 TWh to 36 TWh. Solar energy supplied slightly more than 1 TWh of electricity in 2012. Its contribution rose to 13 TWh in 2019. Electricity generation from wind has increased from 3 TWh in 2005 to 65 TWh in 2019 and now comprises the largest renewable energy source in the electricity mix.

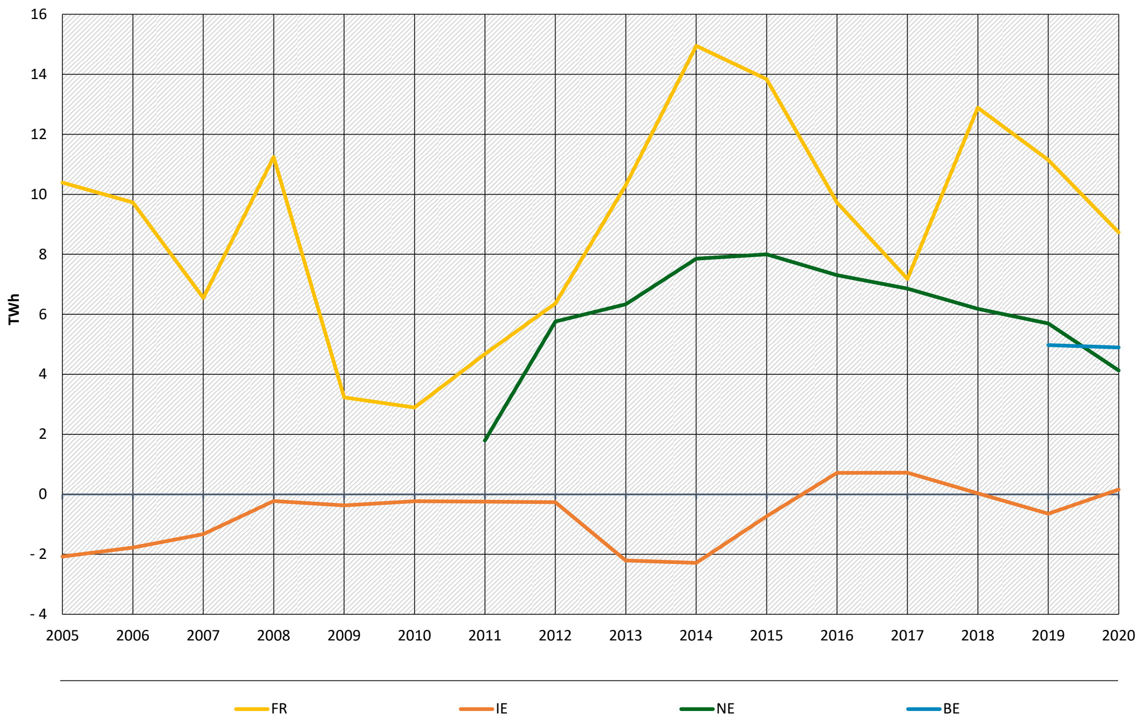
Figure 91: United Kingdom: Electricity generation of renewable energies



Source: Ember (2020).

Figure 92 shows the net electricity exchange between the United Kingdom and its neighbours between 2005 and 2020. France is the country from which the UK imports most electricity. Imports are fluctuating at around 10 TWh (only in 2009 to 2012 were imports considerably lower). With the new cables to the Netherlands coming online in 2011 and to Belgium in 2019, imports to the United Kingdom increased, reaching 9 TWh in 2019 (5 TWh from Belgium and 4 TWh from the Netherlands). Net exports were delivered to Ireland in most years shown. The level of exports to Ireland, however, is low, amounting to between 0 and 2 TWh. This makes the UK a net importer of electricity, as also shown in Figure 90.

Figure 92: United Kingdom: Net import (positive) and net export (negative) of electricity, physical exchange with neighbouring countries



Source: Energy Regulatory Office (2016), Energy Regulatory Office 2019, Department for Business, Energy & Industrial Strategy (2021a).

12.5 Market setting

12.5.1 Regional market allocation and interconnectors

Before the Brexit decision, the UK had been part of the Price Coupling in North-Western Europe (NWE), which was launched in 2014 and became the Multi-Regional Coupling (MRC) project in the same year.

The designated NEMOs (Nominated Electricity Market Operator) in the United Kingdom were EPEX Spot SE and Nord Pool EMCO AS, both as designated NEMO in Great Britain only, and SONI Ltd in Northern Ireland (ACER 2022). The two NEMOs in Great Britain worked together to establish arrangements whereby the EU market coupling process matched bids and offers from across the EU. This resulted in the same day-ahead price being determined for both NEMOs in the EU day-ahead auction and thereby created a single GB clearing price.

After Brexit, electricity is no longer traded through the EU market coupling regime. As a result, the EU market coupling process no longer determines prices for the respective GB day-to-day markets. EPEX and Nord Pool now operate completely separate day-ahead markets, which are settled at different and independent prices.

Since this means efficiency losses, especially in the management of interconnectors to the EU, the government's Department of Business, Energy and Industrial Strategy is now working on procedures to reconnect Great Britain to the European electricity market through a multi-regional loose volume coupling, which would produce a single GB clearing price. This is in line with the Trading and Cooperation Agreement between the UK and the EU (Department for Business, Energy & Industrial Strategy 2021d).

Table 41 shows the maximum forecasted transfer capacities between the United Kingdom and its neighbours according to ENTSO-E data. The UK is connected to Ireland, France the Netherlands and most recently Belgium. The ENTSO-E data for Ireland in the table below covers the interconnection between Ireland and Wales. There is a second interconnector between Ireland and Northern Ireland (540 MW). A new interconnector between England and Norway with a planned capacity of 1,400 MW became operational in October 2021 with an initial capacity of 700 MW (nationalgrid 2021).

Table 41: United Kingdom: Maximum forecasted transfer capacity with neighbouring countries in 2021 (MW)

		BE	FR	IE*	NL	NOR**
UK	to	750	2000	530	1016	700
UK	from	750	2000	500	1016	700

Source: Own data based on ENTSO-E, nationalgrid (2021).

* value for 2019

** new since Oct 2021, initially 700 MW, later expanded to 1400 MW

12.5.2 Electricity market design with reference to conventional power generation plants

The UK introduced a capacity market in 2014 as part of a wider reform of the electricity market. The capacity market is the major policy for ensuring security of electricity supply. It provides payments to both electricity generators and demand response providers by auctions. There are two auctions each year: the T-4 auction is the main auction for most of the capacity needed for delivery in four years' time. The T-1 auctions are top-up auctions shortly before the start of each delivery year (Flexitricity). In the first auctions, mainly existing power plants were awarded contracts, including coal and nuclear power plants. In the first auction in 2014, only slightly more than 5 % of the contracts went to new capacity and only 0.35 % to demand response providers; the result was similar in 2015, though showing an increase in the amount of diesel generators winning contracts, despite these being one of the most polluting forms of generation (Orme 2016).

The diesel generators had benefitted from a loophole in the emission control regulations that has since been closed (Department for Business, Energy & Industrial Strategy 2019). Since the 2021 auction with the delivery date 2024/2025, coal power plants were no longer allowed due to EU emission limits. Based on its own coal phase-out policy, the government held on to these limits even after Brexit (LCP 2021).

13 References

50 Hertz - 50 Hertz Transmission (17 Jan 2018): Stromflüsse nach Tschechien besser steuern, 50Hertz nimmt Phasenschiebertransformatoren in Röhrsdorf in Betrieb. Available online at: https://www.50hertz.com/Portals/1/Dokumente/Markt/Downloadbox%20Phasenschiebertransformatoren/01_Pressemitteilung_50Hertz%20nimmt%20Phasenschiebertransformatoren%20in%20R%C3%B6hrsdorf%20in%20Betrieb.pdf?ver=2018-09-17-174410-000, last accessed on 8 Feb 2021.

50Hertz; Amprion; TenneT; TransnetBW (2021): Report of the German Transmission System Operators on available cross-zonal capacity for the year 2020 pursuant to Article 15(5) Internal Market for Electricity Regulation (EU) 2019/943. Available online at: https://www.netztransparenz.de/portals/1/Compliance_bericht_EN.pdf, last accessed on 27 Jan 2022.

Abrell, J.; Betz, R.; Kosch, M. (2020): The European Emissions Trading System and the German and Polish Electricity Market, Influence of market structures and market regulation on the carbon market (Climate Change, 48/2020). Umweltbundesamt (ed.). Available online at: https://www.umweltbundesamt.de/sites/default/files/medien/5750/publikationen/2020_12_03_cc_48-2020_case_studies_eu_electricity_market.pdf, last accessed on 12 Sep 2022.

ACER (2022): NEMO list. Available online at: https://extranet.acer.europa.eu/en/Electricity/MARKET-CODES/CAPACITY-ALLOCATION-AND-CONGESTION-MANAGEMENT/Pub_Docs/NEMO%20list.pdf, last updated on 16 Dec 2021, last accessed on 27 Jan 2022.

AGEE-Stat (2021): Zeitreihen zur Entwicklung der erneuerbaren Energien in Deutschland. Available online at: https://www.erneuerbare-energien.de/EE/Navigation/DE/Service/Erneuerbare_Energien_in_Zahlen/Zeitreihen/zeitreihen.html, last accessed on 21 Jan 2022.

AtG (1959): Gesetz über die friedliche Verwendung der Kernenergie und den Schutz gegen ihre Gefahren (Atomgesetz), AtG, Version of 1985. Available online at: https://www.gesetze-im-internet.de/atg/AtG.pdf, last accessed on 19 Apr 2022.

Bernd Radowitz (2020): Draft Polish offshore wind act aims to award more than 10GW by 2027. Available online at: https://www.rechargenews.com/wind/draft-polish-offshore-wind-act-aims-to-award-more-than-10gw-by-2027/2-1-738477, last updated on 15 Jan 2020, last accessed on 8 Apr 2021.

Bioenergy International (2021): The Netherlands on track to phase out coal power by 2030 – GlobalData. Available online at: https://bioenergyinternational.com/the-netherlands-on-track-to-phase-out-coal-power-by-2030-globaldata/, last accessed on 12 Sep 2022.

BiznesAlert (2019): Countries of 4M Market Coupling to be connected with Multi Regional Coupling by end of 2020. Available online at: https://biznesalert.com/countries-of-4m-market-coupling-to-be-connected-with-multi-regional-coupling-by-end-of-2020/, last accessed on 8 Apr 2021.

BMUV - Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz (2023): Atomkraftwerke in Deutschland – Abschaltung der noch betriebenen Reaktoren gemäß Atomgesetz (AtG)-BMUV - Infografik. Available online at: https://www.bmuv.de/media/atomkraftwerke-in-deutschland-abschaltung-der-noch-betriebenen-reaktoren-gemaess-atomgesetz-atg, last updated on 29 Jan 2024, last accessed on 29 Jan 2024.

BMWi (2021): Gesamtausgabe der Energiedaten - Datensammlung des BMWi. Available online at: https://www.bmwi.de/Redaktion/DE/Binaer/Energiedaten/energiedaten-gesamt-xls.html, last accessed on 21 Jan 2022.

BNetzA - Bundesnetzagentur; BKartA - Bundeskartellamt (2022): Monitoringbericht 2021, Monitoringbericht gemäß § 63 Abs. 3 i. V. m. § 35 EnWG und § 48 Abs. 3 i. V. m. § 53 Abs. 3 GWB Stand: 15. März 2022. Available online at: https://data.bundesnetzagentur.de/Bundesnetzagentur/SharedDocs/Mediathek/Monitoringberichte/monitoringbericht_energie2021.pdf, last accessed on 13 Nov 2024.

BReg - Bundesregierung der Bundesrepublik Deutschland (ed.) (2021): Mehr Fortschritt wagen. Bündnis für Freiheit, Gerechtigkeit und Nachhaltigkeit, Koalitionsvertrag zwischen SPD, Bündnis 90/Die Grünen und FDP. Available online at: https://www.spd.de/fileadmin/Dokumente/Koalitionsvertrag/Koalitionsvertrag_2021-2025.pdf, last accessed on 25 Sep 2024.

Bundesnetzagentur | SMARD.de (2016-2020): Marktdaten. Available online at: https://www.smard.de/home/downloadcenter/download-marktdaten#!?downloadAttributes=%7B%22selectedCategory%22:3,%22selectedSubCategory%22:31,%22selectedRegion%22:%22DE%22,%22from%22:1546210800000,%22to%22:1609455599999,%22selectedFileType%22:%22XLS%22%7D, last accessed on 25 Jan 2022.

Bundesnetzagentur | SMARD.de (2018): Deutschland und Österreich führen Engpassbewirtschaftung ein. Available online at: https://www.smard.de/page/home/topic-article/444/9828, last accessed on 27 Jan 2022.

Bundesregierung (2020): Gesetz zur Reduzierung und zur Beendigung der Kohleverstromung und zur Änderung weiterer Gesetze (Kohleausstiegsgesetz). Available online at: http://www.bgbl.de/xaver/bgbl/start.xav?startbk=Bundesanzeiger_BGBl&jumpTo=bgbl120s1818.pdf.

CAN Europe (2020): Estonia gives 125 million EUR for fossil fuel production despite the need to tackle both coronavirus and climate crises. Available online at: https://caneurope.org/estonia-shale-oil-plant/.

CBS (2015-2019): Uitwisseling van elektriciteit tussen Nederland en andere landen. Available online at: www.clo.nl/nl059501, last accessed on 15 Nov 2021.

CBS Statline (2021): Hernieuwbare elektriciteit; productie en vermogen. Available online at: https://opendata.cbs.nl/#/CBS/nl/dataset/82610NED/table?dl=32EEF, last updated on 12 Jul 2021, last accessed on 14 Sep 2021.

CBS Statline (2022): Renewable electricity; production and capacity. Available online at: https://opendata.cbs.nl/statline/#/CBS/en/dataset/82610ENG/table?ts=1671183977157, last accessed on 15 Dec 2022.

ČEPS: FAQ. Available online at: https://www.ceps.cz/en/faq, last accessed on 8 Feb 2021.

ČEZ (2021): VIZE 2030 Clean Energy of Tomorrow. Available online at: https://www.cez.cz/webpublic/file/edee/2021/06/press-conference-clean-energy-of-tomorrow.pdf, last accessed on 6 Sep 2021.

CLEW - Clean Energy Wire (2015): Europe's largest electricity market set to split. In collaboration with Jakob Schlandt. Available online at: https://www.cleanenergywire.org/news/europes-largest-electricity-market-set-split, last accessed on 27 Jan 2022.

ClientEarth (2020): Breaking: EU's biggest coal plant must negotiate closure with environmental lawyers, court decides. Available online at: https://www.clientearth.org/latest/press-office/press/breaking-eu-s-biggest-coal-plant-must-negotiate-closure-with-environmental-lawyers-court-decides/, last updated on 22 Sep 2020, last accessed on 8 Apr 2021.

CMS (2015): Electricity law and regulation in the Czech Republic. Available online at: https://cms.law/en/int/expert-guides/cms-expert-guide-to-electricity/czech-republic, last updated on 1 Jan 2015, last accessed on 14 Sep 2021.

CMS (2020a): Renewable energy law and regulation in Czech Republic. Available online at: https://cms.law/en/int/expert-guides/cms-expert-guide-to-renewable-energy/czech-republic, last updated on 18 Dec 2020, last accessed on 8 Sep 2021.

CMS (2020b): Renewable energy law and regulation in France. Available online at: https://cms.law/en/int/expert-guides/cms-expert-guide-to-renewable-energy/france, last accessed on 25 Nov 2021.

CMS (2020c): Renewable Energy Law and Regulation in Spain. Available online at: https://cms.law/en/int/expert-guides/cms-expert-guide-to-renewable-energy/spain, last accessed on 11 Mar 2022.

DEHSt - Deutsche Emissionshandelsstelle (2022): Treibhausgasemissionen 2021 Emissionshandelspflichtige stationäre Anlagen und Luftverkehr in Deutschland (VET-Bericht 2021). Deutsche Emissionshandelsstelle im Umweltbundesamt. Berlin. Available online at: https://www.dehst.de/DE/Europaeischer-Emissionshandel/EU-Emissionshandel-verstehen/Auswertungen-VET-Berichte/auswertungen-vet-berichte_node.html, last accessed on 10 Aug 2022.

DEHSt - Deutsche Emissionshandelsstelle (2023): Treibhausgasemissionen 2022 Emissionshandelspflichtige stationäre Anlagen und Luftverkehr in Deutschland (VET-Bericht 2022). Deutsche Emissionshandelsstelle im Umweltbundesamt. Available online at: https://www.dehst.de/SharedDocs/downloads/DE/publikationen/VET-Bericht-2022.pdf, last accessed on 16 Nov 2023.

del Río, P. and Menzies, C. J. (2021): Auctions for the support of renewable energy in Spain. AURES II (ed.). Available online at: http://aures2project.eu/wp-content/uploads/2021/10/AURES_II_case_study_Spain.pdf, last accessed on 11 Mar 2022.

Dentons (2020a): Dutch subsidies for renewable energy: the end of the SDE+ scheme and the launch of the broadened SDE++. Available online at: https://www.dentons.com/en/insights/alerts/2020/april/16/ams-dutch-subsidies-for-renewable-energy-the-end-of-the-sde-scheme, last accessed on 15 Dec 2022.

Dentons (2020b): Italy: The 2019-2020 incentives regime for renewable energy plants. Available online at: https://www.dentons.com/en/insights/alerts/2020/december/17/fer1-decree-2019-2020-incentives-regime-for-renewable-energy-plants, last accessed on 12 Jul 2021.

Department for Business, Energy & Industrial Strategy (2019): Capacity Market, Five-year Review (2014 – 2019). Available online at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/819760/cm-five-year-review-report.pdf, last accessed on 9 Feb 2022.

Department for Business, Energy & Industrial Strategy (2020): The UK's Integrated National Energy and Climate Plan. Available online at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/991649/uk-integrated-national-energy-climate-plan-necp-31-january-2020.pdf, last accessed on 5 Feb 2022.

Department for Business, Energy & Industrial Strategy (2021a): Digest of UK Energy Statistics (DUKES): electricity, Capacity, net imports and utilisation of interconnectors (DUKES 5.13). Available online at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1006724/DUKES_5.13.xlsx, last accessed on 6 Feb 2022.

Department for Business, Energy & Industrial Strategy (2021b): Digest of UK Energy Statistics (DUKES): electricity, Plant capacity: United Kingdom (DUKES 5.7). Available online at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1006714/DUKES_5.7.xls, last accessed on 27 Jan 2022.

Department for Business, Energy & Industrial Strategy (2021c): End to coal power brought forward to October 2024, Press release. Available online at: https://www.gov.uk/government/news/end-to-coal-power-brought-forward-to-october-2024, last accessed on 31 Jan 2022.

Department for Business, Energy & Industrial Strategy (2021d): GB Wholesale Electricity Market Arrangements, Re-coupling GB auctions for cross-border trade with the EU at the day-ahead timeframe. Available online at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1028393/power-exchange-consultation-gb-wholesale-electricity-market-arrangements.pdf, last accessed on 7 Feb 2022.

Department for Business, Energy & Industrial Strategy (2021e): UK backs new small nuclear technology with £210 million, Press release. Available online at: https://www.gov.uk/government/news/uk-backs-new-small-nuclear-technology-with-210-million, last accessed on 31 Jan 2022.

Department for Business, Energy & Industrial Strategy (2022): Contracts for Difference, Policy paper. Available online at: https://www.gov.uk/government/publications/contracts-for-difference/contract-for-difference, last accessed on 10 Feb 2022.

Deutsche Emissionshandelsstelle (DEHSt) im Umweltbundesamt (2020): Treibhausgasemissionen 2019, Emissionshandelspflichtige stationäre Anlagen und Luftverkehr in Deutschland (VET-Bericht 2019). Berlin. Available online at: https://www.dehst.de/SharedDocs/downloads/DE/publikationen/VET-Bericht-2019.html, last accessed on 13 Nov 2024.

Deutsche Emissionshandelsstelle (DEHSt) im Umweltbundesamt (ed.) (2019): Treibhausgasemissionen 2018, Emissionshandelspflichtige stationäre Anlagen und Luftverkehr in Deutschland (VET-Bericht 2018). Stand: Mai 2019. Available online at: https://www.dehst.de/SharedDocs/downloads/DE/publikationen/VET-Bericht-2018.pdf?__blob=publicationFile&v=2, last accessed on 6 Mar 2023.

Deutsche Emissionshandelsstelle (DEHSt) im Umweltbundesamt (ed.) (2021): Treibhausgasemissionen 2020, Emissionshandelspflichtige stationäre Anlagen und Luftverkehr in Deutschland (VET-Bericht 2020). Berlin. Available online at: https://www.dehst.de/SharedDocs/downloads/DE/publikationen/VET-Bericht-2020.html, last accessed on 13 Nov 2024.

Deutsche Emissionshandelsstelle (DEHSt) im Umweltbundesamt (ed.) (2024): Emissions Situation in European Emissions Trading in 2023, Stationary Installations and Aviation Subject to Emissions Trading in Germany. Available online at: https://www.dehst.de/SharedDocs/downloads/EN/publications/2023_VET-Report.pdf, last accessed on 23 Sep 2024.

Deutscher Bundestag (2022): Entwurf eines Neunzehnten Gesetzes zur Änderung des Atomgesetzes (19. AtGÄndG), Gesetzentwurf der Bundesregierung (Drucksache, 20/4217). Available online at: https://dserver.bundestag.de/btd/20/042/2004217.pdf, last accessed on 29 Jan 2024.

EC - European Commission (2010): National renewable energy action plans 2020. Available online at: https://wayback.archive-it.org/12090/20220307164132/https:/energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/national-renewable-energy-action-plans-2020_en#the-2020-national-renewable-energy-action-plans, last accessed on 18 Nov 2024.

EC - European Commission (2020): State Aid SA.53525 (2020/N) – The Netherlands SDE++ scheme for greenhouse gas reduction projects including renewable energy. Available online at: https://ec.europa.eu/competition/state_aid/cases1/20212/287356_2229457_158_2.pdf, last accessed on 15 Dec 2022.

EC - European Commission (n.d.): European Union Transaction Log (EUTL). Available online at: https://ec.europa.eu/clima/ets/allocationComplianceMgt.do?languageCode=en, last accessed on 30 Mar 2022.

EC - European Commission: Transitional free allocation to electricity generators. Available online at: https://ec.europa.eu/clima/policies/ets/allowances/electricity_en, last accessed on 8 Apr 2021.

Ecovis (2020): Renewable Energy in Romania: PPA available, CfD in the Pipeline, Implementation to Follow. Available online at: https://www.ecovis.com/global/renewable-energy-in-romania-ppa-available-cfd-in-the-pipeline-implementation-to-follow/, last accessed on 18 Feb 2022.

EDF Energy (2024): Hinkley Point C project update, January 2024. Youtube video. Available online at: https://youtu.be/rxhHTpnKX8Y, last accessed on 1 Feb 2024.

EEA - European Environment Agency (2021): EEA greenhouse gas data viewer. European Environment Agency. Available online at: https:/www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer.

EEA - European Environment Agency (2022): Greenhouse gas emission intensity of electricity generation, Data Visualization. Available online at: https://www.eea.europa.eu/data-and-maps/daviz/co2-emission-intensity-10#tab-googlechartid_googlechartid_googlechartid_googlechartid_chart_11111, last updated on 4 Jul 2022, last accessed on 8 Sep 2022.

Eesti Energia (2022): Together with customers on the journey to zero, 2021 Annual report. Available online at: https://www.energia.ee/-/doc/8644186/ettevottest/aastaaruanne/pdf/EE_ENG_2021.pdf.

Eesti Energia, Viru Keemia Grupp, Oil Shale Competence Centre at the Talttech Virumaa College (2021): Estonian Oil Shale Industry Yearbook 2019. Available online at: https://www.vkg.ee/wp-content/uploads/2021/04/Polevkivi_aastaraamat_2019__ENG.pdf, last accessed on 10 Oct 2022.

Eesti Statisika (2005-2019): KE032: ELEKTRIJAAMADE VÕIMSUS. Available online at: https://andmed.stat.ee/et/stat/majandus__energeetika__energia-tarbimine-ja-tootmine__aastastatistika/KE032, last accessed on 12 Jan 2022.

EEX - European Energy Exchange (2023): Erdgas Futures. Available online at: https://www.eex.com/de/marktdaten/erdgas/futures, last updated on 15 Aug 2023, last accessed on 15 Aug 2023.

Electric Insights (2021): Q1 2021: Britain’s transition from coal to biomass to BECCS. Available online at: https://reports.electricinsights.co.uk/q1-2021/britains-transition-from-coal-to-biomass-to-beccs/, last accessed on 12 Sep 2022.

Elering: Electricity market. Available online at: https://elering.ee/en/electricity-market#tab0.

Ember (2020): Electricity Data Explorer. Available online at: https://ember-energy.org/data/electricity-data-explorer/, last updated on 29 Jan 2020, last accessed on 8 Jan 2021.

Ember (ed.) (2021a): Onyx Power Maasvlakte Analysis. Available online at: https://www.somo.nl/wp-content/uploads/2021/04/Onyx-Power-Report.pdf, last accessed on 20 Sep 2021.

Ember (ed.) (2021b): Uniper Maasvlakte 3 Analysis. Available online at: https://www.somo.nl/wp-content/uploads/2021/04/Uniper-Report.pdf, last accessed on 15 Dec 2022.

Enel (ed.) (2023): Capital Markets Day, 2024-26 Strategic Plan. Available online at: https://www.enel.com/content/dam/enel-com/documenti/investitori/informazioni-finanziarie/2023/2024-2026-strategic-plan.pdf, last accessed on 31 Jan 2024.

Energie & Management (2023): Kernkraftwerk Flamanville 3 wird teurer. Available online at: https://www.energie-und-management.de/nachrichten/energieerzeugung/detail/kernkraftwerk-flamanville-3-wird-teurer-205461, last accessed on 29 Jan 2024.

Energie-Chronik (2011): E.ON legt in Frankreich fünf Kohle-Kraftwerke still. Available online at: https://www.energie-chronik.de/110611.htm, last accessed on 18 Nov 2021.

Energy Regulatory Office (2016): Roční zpráva o provozu ES ČR 2016. Available online at: https://eru.gov.cz/sites/default/files/obsah/prilohy/rocnizpravaprovozes2016.xlsx, last accessed on 18 Nov 2024.

Energy Regulatory Office (2019): Roční zpráva o provozu elektrizační soustavy ČR pro rok 2019. Available online at: https://eru.gov.cz/sites/default/files/obsah/prilohy/rocnizpravaprovozes2019.xlsx, last accessed on 18 Nov 2024.

ENTSO-E (2005-2015): Country Packages, Germany.

ENTSO-E (2013, 2014): Statistics and Data, Monthly Statistics Reports. Available online at: https://www.entsoe.eu/publications/statistics-and-data/#monthly-statistics-reports, last accessed on 15 Nov 2021.

ENTSO-E (2016-2019): Transparency Platform, Cross border physical flow. Available online at: https://transparency.entsoe.eu/transmission-domain/physicalFlow/show?name=&defaultValue=false&viewType=TABLE&areaType=BORDER_CTY&atch=false&dateTime.dateTime=15.03.2019+00:00|EET|DAY&border.values=CTY|10Y1001A1001A39I!CTY_CTY|10Y1001A1001A39I_CTY_CTY|10YFI-1--------U&dateTime.timezone=EET_EEST&dateTime.timezone_input=EET+(UTC+2)+/+EEST+(UTC+3).

ENTSO-E (2019): Installed Capacity Per Production Type. Available online at: https://transparency.entsoe.eu/generation/r2/installedGenerationCapacityAggregation/show, last accessed on 18 Nov 2024.

ENTSO-E: Transparency Platform, Forecasted Transfer Capacities - Year Ahead. Available online at: https://transparency.entsoe.eu/transmission-domain/ntcYear/show, last accessed on 16 Nov 2021.

Epex Spot (2018): Exchange Council looks forward to new market launches in the Nordic, Baltic countries and Poland. Available online at: https://www.epexspot.com/en/news/exchange-council-looks-forward-new-market-launches-nordic-baltic-countries-and-poland.

Epex Spot: European Market Coupling, Price Coupling of Regions (PCR). Available online at: https://www.epexspot.com/en/marketcoupling.

Equinor (2020): Equinor joins Letter of Intent on offshore wind cooperation in Poland. Available online at: https://www.equinor.com/en/where-we-are/poland/02072020-cooperation-offshore-wind-poland.html, last updated on 1 Jul 2020, last accessed on 8 Apr 2021.

Err.ee (2021a): Coalition agreement: Center-Reform government 2021-2023. Available online at: https://news.err.ee/1608086476/coalition-agreement-center-reform-government-2021-2023, last accessed on 20 Jan 2022.

Err.ee (2021b): Eesti Energia ehitas Auvere jaama pea põlevkivivabaks. Available online at: https://www.err.ee/1608399551/eesti-energia-ehitas-auvere-jaama-pea-polevkivivabaks, last accessed on 14 Jan 2022.

Estonia (2023): Draft update of Estonia's National Energy and Climate Plan for 2030, Notification by Estonia to the European Commission pursuant to Articla 14(1) of Regulation (EU) 2018/1999. Available online at: https://commission.europa.eu/system/files/2023-08/Estonia_Draft_Updated_NECP_2021-2030_en_1.pdf, last accessed on 1 Feb 2024.

Euracoal (2020): Coal industry across Europe, 7th edition, February 2020.

Euractiv (2020): Poland to seek EU approval for state aid to build nuclear plant. Available online at: https://www.euractiv.com/section/energy/news/poland-to-seek-eu-approval-for-state-aid-to-build-nuclear-plant/, last accessed on 8 Apr 2021.

Euractiv (2021): EU ministers give Romania’s recovery plan their blessing. In collaboration with Bogdam Neagu. Available online at: https://www.euractiv.com/section/politics/short_news/eu-ministers-give-romanias-recovery-plan-their-blessing/, last accessed on 17 Feb 2022.

Europäisches Parlament und Europäischer Rat (2019): Verordnung (EU) 2019/ 943 des Europäischen Parlaments und des Rates - vom 5. Juni 2019 - über den Elektrizitätsbinnenmarkt, (Neufassung). Available online at: https://www.clearingstelle-eeg-kwkg.de/sites/default/files/VERORDNUNG%20%28EU%29%202019.943%20%C3%BCber%20den%20Elektrizit%C3%A4tsbinnenmarkt.pdf, last accessed on 8 Apr 2021.

Europe Beyond Coal (2022): Coal Exit Tracker. Available online at: https://beyond-coal.eu/coal-exit-tracker/, last accessed on 22 Sep 2022.

Farand, C. (2020): Poland agrees coal mining phase out with unions by 2049. Available online at: https://www.climatechangenews.com/2020/09/25/poland-agrees-coal-mining-phase-unions-2049/, last accessed on 8 Apr 2021.

Flexitricity: Capacity Market. Available online at: https://www.flexitricity.com/services/capacity-market/, last accessed on 8 Feb 2022.

Global Energy Monitor Wiki (2020a): Jaworzno power station. Available online at: https://www.gem.wiki/Jaworzno_power_station, last updated on 17 Dec 2020, last accessed on 8 Apr 2021.

Global Energy Monitor Wiki (2020b): Prunerov Power Station. Available online at: https://www.gem.wiki/Prunerov_Power_Station, last updated on 9 Jun 2020, last accessed on 8 Feb 2021.

Global Energy Monitor Wiki (2021a): Ostroleka power station. Available online at: https://www.gem.wiki/Ostroleka_power_station, last updated on 17 Feb 2021, last accessed on 18 Feb 2021.

Global Energy Monitor Wiki (2021b): Rovinari power station. Available online at: https://www.gem.wiki/Rovinari_power_station, last accessed on 16 Feb 2022.

Global Energy Monitor Wiki (2022a): Oltenia Energy Complex. Available online at: https://www.gem.wiki/Oltenia_Energy_Complex, last accessed on 17 Feb 2022.

Global Energy Monitor Wiki (2022b): Provence power station. Available online at: https://www.gem.wiki/Provence_power_station, last accessed on 20 Dec 2022.

Gotzens, F.; Heinrichs, H.; Hörsch, J.; Hofmann, F. (2019): Performing energy modelling exercises in a transparent way, The issue of data quality in power plant databases. Available online at: https://www.sciencedirect.com/science/article/pii/S2211467X18301056, last accessed on 5 Aug 2024.

Government of Czech Republic (ed.) (2019): National Energy and Climate Plan of the Czech Republic. Available online at: https://commission.europa.eu/energy-climate-change-environment/implementation-eu-countries/energy-and-climate-governance-and-reporting/national-energy-and-climate-plans_en, last accessed on 18 Nov 2024.

Government of France (ed.) (2023): National Energy and Climate Plan of France. Available online at: https://commission.europa.eu/publications/france-draft-updated-necp-2021-2030_en, last accessed on 18 Nov 2024.

Government of Romania (2023): Integrated National Energy and Climate Plan of Romania, 2021-2030 Update First draft version. Available online at: https://commission.europa.eu/system/files/2023-11/ROMANIA%20-%20DRAFT%20UPDATED%20NECP%202021-2030.pdf, last accessed on 29 Jan 2024.

Government of Romania (ed.) (2020): The 2021-2030 Integrated National Energy and Climate Plan. Available online at: https://commission.europa.eu/energy-climate-change-environment/implementation-eu-countries/energy-and-climate-governance-and-reporting/national-energy-and-climate-plans_en#national-energy-and-climate-plans-2021-2030, last accessed on 18 Nov 2024.

Government of Spain (ed.) (2020): Integrated National Energy and Climate Plan 2021-2030. Available online at: https://energy.ec.europa.eu/system/files/2020-06/es_final_necp_main_en_0.pdf, last accessed on 7 Mar 2022.

Government of the Netherlands: Nuclear energy. Available online at: https://www.government.nl/topics/renewable-energy/nuclear-energy, last accessed on 20 Sep 2021.

Grantham Research Institute on Climate Change and the Environment (2019): What is a carbon price and why do we need one? Available online at: https://www.lse.ac.uk/granthaminstitute/explainers/what-is-a-carbon-price-and-why-do-we-need-one/, last accessed on 18 Nov 2024.

Gusilov, E. (2018): Does Romania need a capacity market? Available online at: https://energyindustryreview.com/analysis/does-romania-need-capacity-market/, last accessed on 18 Nov 2024.

Haves, E. (2021): Nuclear power in the UK. Available online at: https://lordslibrary.parliament.uk/nuclear-power-in-the-uk/, last accessed on 18 Nov 2024.

Hermann, H. and Matthes, F. C. (2022): Die deutsche Braunkohlenwirtschaft 2021, Historische Entwicklungen, Ressourcen, Technik, wirtschaftliche Strukturen und Umweltauswirkungen. Oeko-Institut; European Climate Foundation. Agora Energiewende (ed.). Berlin. Available online at: https://www.agora-energiewende.de/veroeffentlichungen/die-deutsche-braunkohlenwirtschaft-2021/, last accessed on 18 Nov 2024.

HM Government (2021): Net Zero Strategy: Build Back Greener. Available online at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1033990/net-zero-strategy-beis.pdf, last accessed on 5 Feb 2022.

IAEA (2018): Country Nuclear Power Profiles 2018 Edition. Available online at: https://www-pub.iaea.org/MTCD/Publications/PDF/cnpp2018/countryprofiles/CzechRepublic/CzechRepublic.htm, last accessed on 8 Feb 2021.

ICE - Intercontinental Exchange (2022): EUA Futures. Available online at: https://www.theice.com/products/197/EUA-Futures/data?marketId=5474736, last accessed on 12 May 2022.

ICIS (2020): Poland plans for the exclusion of existing lignite and coal capacities from capacity market auctions. Available online at: https://www.icis.com/explore/resources/news/2020/09/10/10551211/poland-plans-for-the-exclusion-of-existing-lignite-and-coal-capacities-from-capacity-market-auctions, last updated on 10 Sep 2020, last accessed on 8 Apr 2021.

IEEFA (2021): Polish Parliament passes offshore wind act, sets stage for major buildout through 2030. In collaboration with IEEFA. Available online at: https://ieefa.org/polish-parliament-passes-offshore-wind-act-sets-stage-for-major-buildout-through-2030/, last accessed on 9 Apr 2021.

Julian Schwartzkopff, C. L. (2015): G7 Coal Phase out: France, A review for oxfam international. Available online at: https://www.e3g.org/wp-content/uploads/France_G7_Analysis_September_2015.pdf, last accessed on 18 Nov 2021.

Kendziorski, M.; Zozmann, E.; Kunz, F. (2020): National generation capacity. DOI: 10.25832/national_generation_capacity/2020-10-01.

Koenig, H.; Liu, K.; Piasecki, F.; Preuß, M.; Maywald, J.; Gawlikowska-Fyk, A.; Mackowiak-Pandera, J.; Litz, P. (2020): Modernising the European lignite triangle, Towards a safe, cost-effective and sustainable energy transition. Agora Energiewende and Forum Energii (ed.). Available online at: https://www.agora-energiewende.de/fileadmin/Partnerpublikationen/2020/Lignite_Triangle/EN-Modernising_the_European_lignite_triangle.pdf, last accessed on 13 Nov 2024.

Komora OZE - Komora obnovitelných zdrojů energie (2021): Senát opravil vady poslanecké verze novely. Ta přináší restart obnovitelných zdrojů a modernizaci energetiky. Available online at: https://komoraoze.cz/senat-opravil-vady-poslanecke-verze-novely-ta-prinasi-restart-obnovitelnych-zdroju-a-modernizaci-energetiky/, last accessed on 18 Nov 2024.

Krzysztoszek, A. (2022): Poland to slow coal phase-out process, maintain 2049 end-date. Available online at: https://www.euractiv.com/section/energy/news/poland-to-slow-coal-phase-out-process-maintain-2049-end-date/, last accessed on 15 Dec 2022.

LCP - Lane Clark & Peacock (ed.) (2021): Review of the T-4 2024/25 GB capacity market auction. Frontier Economics. Available online at: https://www.frontier-economics.com/media/mofmjyn0/cm-2021-briefing.pdf, last accessed on 18 Nov 2024.

lightbox (2021): The new electricity market zones: what you need to know. Available online at: https://lightbox.terna.it/en/new-electricity-market-zones, last updated on 8 Feb 2021, last accessed on 15 Jul 2021.

Littlecott, C.; Burrows, L.; Skillings, S. (2018): Insights from the UK phase out experience: Report to Chile Decarbonisation Roundtable. E3G. Available online at: https://www.jstor.org/stable/pdf/resrep21851.1.pdf, last accessed on 13 Nov 2024.

Lyan, M. (2019): Chauffage urbain : Grenoble atteint un record d'énergies vertes. Available online at: https://region-aura.latribune.fr/territoire/politique-publique/2019-09-03/chauffage-urbain-grenoble-atteint-un-record-d-energies-vertes-827023.html, last accessed on 18 Nov 2021.

Magdalena Januszek (2020): Co dalej z elektrociepłownią w Puławach? Potrzebna decyzja. Available online at: https://inzynieria.com/energetyka/wiadomosci/59400,co-dalej-z-elektrocieplownia-w-pulawach-potrzebna-decyzja, last updated on 16 Sep 2020, last accessed on 8 Apr 2021.

Magnus commodities (2019): Towards the end of nuclear power in Spain. In collaboration with Ismael Abordan. Available online at: https://www.magnuscmd.com/toward-the-end-of-nuclear-power-in-spain/, last accessed on 9 Mar 2022.

Majandus- ja Kommunikatsiooniministeerium (2007): Eesti energeetika arvudes. Available online at: https://energiatalgud.ee/sites/default/files/images_sala/2/2f/MKM._Eesti_energeetika_arvudes_2007.pdf.

Ministère de la transition écologique (2021): Dispositifs de soutien aux énergies renouvelables. Available online at: https://www.ecologie.gouv.fr/dispositifs-soutien-aux-energies-renouvelables, last accessed on 25 Nov 2021.

Ministerstvo průmyslu a obchodu (2021): Czech Republic Strategy of stabilization and development of district heating, 8th Plenary Meeting Concerted Action for the Energy Efficiency Directive. Available online at: https://www.ca-eed.eu/Search?search=Czech, last updated on 24 Mar 2021, last accessed on 14 Sep 2021.

Ministerstwo Klimatu i Środowiska: National Energy and Climate Plan for the years 2021-2030. Available online at: https://www.gov.pl/web/klimat/national-energy-and-climate-plan-for-the-years-2021-2030, last accessed on 15 Mar 2021.

Ministerul Investitiilor si Proiectelor Europene (ed.) (2021): Planul National de Redresare si Rezilienta al Romaniei. Available online at: https://mfe.gov.ro/wp-content/uploads/2021/10/facada6fdd5c00de72eecd8ab49da550.pdf, last accessed on 18 Feb 2022.

Ministry of Economic Affairs and Climate Policy (2019): Integrated National Energy and Climate Plan, 2021-2030. The Netherlands. Available online at: https://ec.europa.eu/energy/sites/default/files/documents/nl_final_necp_main_en.pdf, last accessed on 1 Nov 2021.

Ministry of Economic Development, Ministry of the Environment and Protection of Natural Resources and the Sea, Ministry of Infrastructure and Transport (2019): Integrated National Energy and Climate Plan, Italy. Available online at: https://ec.europa.eu/energy/sites/default/files/documents/it_final_necp_main_en.pdf, last accessed on 6 Jul 2021.

MITECO - Ministerio para la Transición Ecológica y el Reto Demográfico (2021): Proyecto de Orden por la que se crea un mercado de capacidad en el sistema eléctrico español. Available online at: https://www.miteco.gob.es/es/energia/participacion/2023-y-anteriores/detalle-participacion-publica-k-409.html, last accessed on 18 Nov 2024.

Montel (2021): EDF's Levy confirms Flamanville EPR start-up in 2023. In collaboration with Sophie Tetrel. Available online at: https://www.montelnews.com/news/1194318/edfs-levy-confirms-flamanville-epr-start-up-in-2023, last accessed on 18 Nov 2021.

nationalgrid (2021): National Grid powers up world's longest subsea interconnector between the UK and Norway. Available online at: https://www.nationalgrid.com/national-grid-powers-worlds-longest-subsea-interconnector-between-uk-and-norway, last accessed on 20 Dec 2022.

Neagu, B.andTaylor, K. (2021): Romania commits to phase out coal by 2032. Available online at: https://www.euractiv.com/section/energy/news/romania-will-phase-out-coal-by-2032/, last accessed on 17 Feb 2022.

Nord Pool (2010): No. 50/2010 NPS - Intraday market to be launched in Estonia in October. Available online at: https://www.nordpoolgroup.com/en/message-center-container/newsroom/exchange-message-list/2010/09/No-502010-NPS---Intraday-market-to-be-launched-in-Estonia-in-October/, last accessed on 18 Nov 2024.

NS Energy: Ostroleka C Power Plant. Available online at: https://www.nsenergybusiness.com/projects/ostroleka-c-power-plant-poland/#, last accessed on 23 Feb 2021.

Oeko-Institut (2013): Auswirkungen des deutschen Kernenergie-Ausstiegs auf den Stromaustausch mit den Nachbarländern. In collaboration with Charlotte Loreck, Hauke Herrmann, Dr. Felix Chr. Matthes, Lukas Emele, Lothar Rausch. Available online at: https://www.oeko.de/oekodoc/1634/2013-004-de.pdf.

Orme, B. (2016): Guest post: Understanding the government's capacity market. Available online at: https://www.carbonbrief.org/guest-post-understanding-governments-capacity-market, last accessed on 8 Feb 2022.

OTE (2021): The European Day-Ahead Market Successfully Coupled. Contact: Zuzana Dvořáková. Available online at: https://www.ote-cr.cz/cs/o-spolecnosti/files-novinky/press-release_interim-coupling.pdf, last accessed on 1 Feb 2024.

Overheid.nl (2019): Wet verbod op kolen bij elektriciteitsproductie. Available online at: https://wetten.overheid.nl/BWBR0042905/2019-12-20, last updated on 20 Dec 2019, last accessed on 20 Sep 2021.

PBL - Planbureau voor de Leefomgeving (2021): Netherlands Climate and Energy Outlook 2021, Summary. Available online at: https://www.pbl.nl/sites/default/files/downloads/pbl-2021-netherlands-climate-and-energy-outlook_2021-summary-4709.pdf, last accessed on 1 Nov 2021.

PGE (2019): Fortführung des Abbaus der Braunkohlelagerstätte Turów, Die Umweltverträglichkeitsprüfung. Bogatynia.

Planelles, M. (2021): 10 años de Fukushima: golpe a la reputación de una energía en retroceso. Available online at: https://elpais.com/clima-y-medio-ambiente/2021-03-09/10-anos-de-fukushima-golpe-a-la-reputacion-de-una-energia-en-retroceso.html, last accessed on 9 Mar 2022.

PSE (2020): Raport 2019 KSE. In collaboration with PSE. Available online at: https://www.pse.pl/dane-systemowe/funkcjonowanie-kse/raporty-roczne-z-funkcjonowania-kse-za-rok/raporty-za-rok-2019.

PV Magazine (2022): Romania to hold first renewables tender in H1 2022. Available online at: https://www.pv-magazine.com/2022/01/05/romania-to-hold-first-renewables-tender-in-h1-2022/, last accessed on 18 Feb 2022.

RAP - The Regulatory Assistance Project (2018): Report on the Polish power system. Version 2.0, Study commissioned by Agora Energiewende. Available online at: https://www.agora-energiewende.org/publications/report-on-the-polish-power-system-2018#downloads, last accessed on 13 Nov 2024.

RED Electrica de Espana (2005-2019): Exchanges, Cross-Border Exchange Balance - Physical (GWh). Available online at: https://www.ree.es/en/datos/exchanges, last accessed on 18 Mar 2022.

RED Electrica de Espana (2006-2014): Serie histórica de potencia instalada. Available online at: https://www.ree.es/sites/default/files/11_PUBLICACIONES/Documentos/6_Potencia_instalada-20141231.xlsm, last accessed on 24 Feb 2022.

RED Electrica de Espana (2015-2019): Installed Capacity, Peninsular. Available online at: https://www.ree.es/en/datos/generation/installed-capacity, last accessed on 24 Feb 2022.

REE - Red Electrica de Espana (2022): International interconnections. Available online at: https://www.ree.es/en/activities/operation-of-the-electricity-system/international-interconnections, last accessed on 12 May 2022.

Republic of Estonia, Ministry of Economic Affairs and Communications: Electricity market, Power system of the Republic of Estonia. Available online at: https://www.mkm.ee/en/objectives-activities/energy-sector/electricity-market, last accessed on 20 Jan 2022.

RES LEGAL Europe (2019a): Czech Republic. Feed-in tariff (State-purchasing Price). In collaboration with Boris Valach. Available online at: http://www.res-legal.eu/search-by-country/czech-republic/single/s/res-e/t/promotion/aid/feed-in-tariff-act-on-the-promotion-of-the-use-of-res/lastp/119, last updated on 10 Jan 2019, last accessed on 8 Sep 2021.

RES LEGAL Europe (2019b): France, Summary of support schemes. Available online at: http://www.res-legal.eu/en/search-by-country/france/tools-list/c/france/s/res-e/t/promotion/sum/132/lpid/131/, last accessed on 25 Nov 2021.

RES LEGAL Europe (2019c): Promotion in Czech Republic. In collaboration with Boris Valach. Available online at: http://www.res-legal.eu/search-by-country/czech-republic/tools-list/c/czech-republic/s/res-e/t/promotion/sum/120/lpid/119/, last updated on 10 Jan 2019, last accessed on 8 Sep 2021.

RES LEGAL Europe (2019d): Promotion in Romania, Means of support. In collaboration with Cristina Blajin. Available online at: http://www.res-legal.eu/search-by-country/romania/tools-list/c/romania/s/res-e/t/promotion/sum/184/lpid/183/, last accessed on 18 Feb 2022.

RES LEGAL Europe (2019e): Promotion in Spain. Available online at: http://www.res-legal.eu/search-by-country/spain/tools-list/c/spain/s/res-e/t/promotion/sum/196/lpid/195/, last accessed on 11 Mar 2022.

RES LEGAL Europe (2019f): Promotion in United Kingdom. Available online at: http://www.res-legal.eu/search-by-country/united-kingdom/tools-list/c/united-kingdom/s/res-e/t/promotion/sum/204/lpid/203/, last accessed on 9 Feb 2022.

Reuters (2022a): Estonia turns back to shale oil as it cuts off Russian power. Available online at: https://www.reuters.com/business/energy/estonia-turns-back-shale-oil-it-cuts-off-russian-power-2022-10-19/, last accessed on 26 Oct 2022.

Reuters (2022b): Romanian minister says EU funds to drive green energy surge. Available online at: https://www.reuters.com/world/europe/romanian-minister-says-eu-funds-drive-green-energy-surge-2022-01-14/, last accessed on 18 Feb 2022.

Reuters (24 May 2021): Czech government to look at speedier coal exit than 2038 target. Available online at: https://www.reuters.com/article/czech-coal-idUSL5N2NB20Z, last accessed on 6 Sep 2021.

Robb, D. (2019): Phasing out coal in Denmark via bioenergy-based CHP. Available online at: https://www.renewableenergyworld.com/baseload/phasing-out-coal-in-denmark-via-bioenergybased-chp/, last accessed on 12 Sep 2022.

Romanian Energy Regulatory Authority (ed.) (2019): National Report 2018. Available online at: https://arhiva.anre.ro/en/about-anre/annual-reports-archive, last accessed on 18 Nov 2024.

Rosca, O. (2019): Moldova set to build power link with Romania. Available online at: https://www.ebrd.com/news/2019/moldova-set-to-build-power-link-with-romania.html, last accessed on 21 Feb 2022.

Rossetto, N. (2015): An oversized electricity system for Italy. In: *ISPI Analysis* (290). Available online at: https://www.researchgate.net/publication/284142421_AN_OVERSIZED_ELECTRICITY_SYSTEM_FOR_ITALY, last accessed on 12 Jul 2021.

RTE (2015-2020): Exchanges, Flux physiques. Available online at: https://www.services-rte.com/fr/telechargez-les-donnees-publiees-par-rte.html?category=exchange&type=physical_flow, last accessed on 23 Nov 2021.

RTE (2015-2021): Capacité installée des unités de plus de 1 MW agrégée par filière de production. Available online at: https://www.services-rte.com/fr/visualisez-les-donnees-publiees-par-rte/capacite-installee-de-production.html, last accessed on 17 Nov 2021.

RTL Nieuws (2020): Eigenaar wil kwart miljard subsidie om kapotte kolencentrale te sluiten. Available online at: https://www.rtlnieuws.nl/economie/bedrijven/artikel/5192976/investeerder-wil-238-miljoen-subsidie-om-onyx-kolencentrale, last updated on 27 Oct 2020, last accessed on 21 Sep 2021.

RWE: Amer power plant, Facts and figures. Available online at: https://benelux.rwe.com/en/locations/amer-power-plant, last accessed on 20 Sep 2021.

RWE: Eemshaven power plant. Available online at: https://benelux.rwe.com/en/locations/eemshaven-power-plant, last accessed on 15 Dec 2022.

Schönherr (2013): Romania: Changes to Romania's Renewable Energy Laws. In collaboration with Monica Cojocaru, M. P. Available online at: https://www.schoenherr.si/fileadmin/tx_news/schoenherr_Changes_to_Romanias_Renewable_Energy_Laws.pdf.

Serbia Energy (2015): Romania: The alarming situation, the deadlock in trade green certificates. Available online at: https://serbia-energy.eu/romania-the-alarming-situation-the-deadlock-in-trade-green-certificates/, last accessed on 18 Feb 2022.

Soltysinski Kawecki Szlezak (2018): Proposal of the new incentive scheme for electricity generated in high-efficiency CHP units. Available online at: https://skslegal.pl/wp-content/uploads/2018/05/Alert-CHP-April-2018.pdf, last accessed on 8 Apr 2021.

Spasic, V. (2021): Bulgaria-Romania day-ahead market coupling completed. Available online at: https://balkangreenenergynews.com/bulgaria-romania-day-ahead-market-coupling-completed/, last accessed on 22 Feb 2022.

Statistik der Kohlenwirtschaft e.V. (2020): Braunkohle im Überblick. Available online at: https://kohlenstatistik.de/wp-content/uploads/2019/10/bk-ueberblick-1.xlsx, last updated on 04.2020, last accessed on 8 Apr 2021.

Talttech Virumaa College Oil Shale Competence Centre, Eesti Energia, Viru Keemia Grupp, Kivioli Keemiatööstus (2022): Estonian Oil Shale Industry Yearbook 2020. Available online at: https://www.vkg.ee/wp-content/uploads/2022/05/eesti_polevkivitoostuse_aastaraamat_2020__eng_web.pdf, last accessed on 10 Oct 2022.

Terna (2005-2019): Impianti di generazione. Available online at: https://www.terna.it/it/sistema-elettrico/statistiche/pubblicazioni-statistiche, last accessed on 31 May 2021.

Terna (2006-2019): Dati generali. Available online at: https://www.terna.it/it/sistema-elettrico/statistiche/pubblicazioni-statistiche, last accessed on 13 Jul 2021.

TGE: TGE as a Nominated Electricity Market Operator. Available online at: https://tge.pl/EN_TGE_NEMO, last accessed on 7 Jul 2021.

TGE: TGE history. Available online at: https://www.tge.pl/about-tge#historia, last accessed on 8 Apr 2021.

The Law Reviews (2021): The Renewable Energy Law Review: Spain. In collaboration with José Antonio García, Pedro L Marín and Jack Stirzaker. Available online at: https://thelawreviews.co.uk/title/the-renewable-energy-law-review/spain, last accessed on 11 Mar 2022.

TSCNET Services (2020): Delay for Interim Coupling. Available online at: https://www.tscnet.eu/delay-for-interim-coupling/.

van de Graaf, W. E.; van Geuns, L.; Boersma, T. (2018): The termination of Groningen gas production - background and next steps. Columbia Center on Global Energy Policy (ed.). Available online at: https://energypolicy.columbia.edu/sites/default/files/pictures/CGEP_Groningen-Commentary_072518_0.pdf, last accessed on 12 May 2022.

Wärtsilä (2018): Kiisa ERPP I & II, Case Study. Available online at: https://cdn.wartsila.com/docs/default-source/power-plants-documents/downloads/reference-sheets/wartsila-power-plants-reference-kiisa-estonia.pdf?sfvrsn=3586e845_6, last accessed on 14 Jan 2022.

World Nuclear Association (2021): Nuclear Power in Romania. Available online at: https://world-nuclear.org/information-library/country-profiles/countries-o-s/romania.aspx, last accessed on 17 Feb 2022.

World Nuclear Association (2022): Nuclear Power in France. Available online at: https://world-nuclear.org/information-library/country-profiles/countries-a-f/france.aspx.

World nuclear news (2021a): Dutch study finds commercial support for nuclear new build. Available online at: https://world-nuclear-news.org/Articles/Dutch-study-finds-commercial-support-for-nuclear-n, last updated on 8 Jul 2021, last accessed on 20 Sep 2021.

World nuclear news (2021b): Estonia to assess adoption of nuclear energy. Available online at: https://www.world-nuclear-news.org/Articles/Estonia-appoints-working-group-to-assess-adoption.

Xing Zhang (2020): Support mechanisms for cofiring biomass with coal. Available online at: https://www.researchgate.net/profile/Xing-Zhang/publication/342105941_SUPPORT_MECHANISMS_FOR_COFIRING_BIOMASS_WITH_COAL/links/5ee23946a6fdcc73be703f04/SUPPORT-MECHANISMS-FOR-COFIRING-BIOMASS-WITH-COAL.pdf?origin=publication_detail, last accessed on 15 Dec 2022.

ZE PAK (1 Oct 2020): Green directions of ZE PAK, Green directions of ZE PAK strategy from the group of Zygmunt Solorz accepted – end to coal energy by 2030 at the latest. Available online at:

https://zepak.com.pl/en/about-us/press-office/news/11644-green-directions-of-ze-pak.html, last accessed on 6 Apr 2021.