ENERGY PARTNERSHIP
CHILE-ALEMANIA

Ministerio de Energía
Gobierno de Chile

Supported by:

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on the basis of a decision by the German Bundestag

Phasing Out Coal in Chile and Germany

A Comparative Analysis

Agora Energiewende

Dear reader,

“Coal exit” is a buzzword in the international energy transition. Since the world’s first coal power station went into operation in 1882, coal has been the world’s primary source of energy for generating electricity. Accordingly, coal demand for electricity production has grown enormously in recent decades and is currently responsible for some 20 per cent of global anthropogenic GHG emissions.

With such an immense GHG footprint, the continued use of coal is not compatible with the need for rapid decarbonization. More importantly, given progress in the development of renewable technologies, including associated cost reductions, continued reliance on coal generation is economically irrational.

While the rate of coal power capacity expansion is still exceeding that of plant closure, the actual utilization of the ever-growing coal fleet has been shrinking. Since 2018, this has led to a reduction in global coal generation of 7 per cent. Against the backdrop of the pandemic induced economic crisis, the increasing competitiveness of renewable generation, and policy action to spur green economic recovery, the demise of coal seems unavoidable.

This is good news for the climate and the overall efficiency of our economies. But the structural changes associated with exiting coal can be profound. For this reason, policymakers must work to reconcile the conflicting interests of investors, workers, and communities.

In this publication, we analyse the experiences that Chile and Germany have gathered in this area to distil lessons for policymakers needing to navigate the challenges of exiting coal in their own countries.

We hope you find this report to be both stimulating and enlightening.

Best regards,

Philipp D. Hauser | Rainer Schröer

Key findings at a glance:

1. Phasing-out coal is an inevitable and profound structural change that must be managed carefully, involving stakeholders from affected regions. An early and comprehensive engagement of interested parties allows the reconciliation of diverging interests – defining adequate measures for a just transition and lasting stakeholder support.

2. Substituting coal with renewable electricity is key for direct and indirect electrification strategies to transform national and international energy markets. Sound energy planning and an effective and adaptive policy framework with a focus on supply- and demand-side flexibility will ensure the success and efficiency of the process.

3. A consensual vision and strategy for exiting coal is a political and economic signal that provides attractive investment opportunities. Agreements must be solid as well as flexible to adapt to rapid changes in technology, investment behaviours, and climate policies.

4. Investors are ready to embrace the opportunities and business models offered by the decarbonization of energy systems. As costs of renewable energy technologies continue to fall, the roll-out of a smart, digitized, decentralized, flexible, and renewable energy system represents an attractive economic growth opportunity for investors and nations.

Imprint

This comparative study was carried out on behalf of the Energy Partnership Chile-Alemania.
Leading partners are the German Ministry for Economy and Energy (BMWi) and the Chilean Ministry for Energy (ME), together with numerous affiliated institutions. The GIZ, the executive body of the partnership, can look back to more than ten years of successful cooperation with the Chilean Ministry of Energy.

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Section A – Coal Phase-out in Chile

1. Country overview of Chile and its energy system

1.1 Socio-economic structure

With nearly 20 million inhabitants and an annual GDP of 290 billion USD, Chile is South America's fourth largest economy. Chile has a free-market economy that is recognized as one of the most robust in South America; the country was ranked 33rd in the World Economic Forum's Global Competitiveness Report (2019). Following the economic progress achieved between 1990 and 2010, Chile was the first South American country to join the OECD (2010).

Since 2011, Chile has been considered a high-income country by the World Bank (2011). The country has strong multilateral partnerships, including numerous agreements for free trade and economic and environmental cooperation. Chile has commercial association agreements with the European Union; free trade agreements with the US, China, and South Korea (among others); and is part of the Trans-Pacific Strategic Agreement. These agreements allow the country to access export markets that represent 88 per cent of the world's GDP (Invest Chile, 2020). Mining exports represent 13 per cent of Chile's GDP (Central Bank of Chile, 2020). As the mining sector is highly dependent on a reliable supply of energy and Chile does not have significant fossil fuel reserves, the country has historically been dependent on coal, oil, and natural gas imports. Table A1 provides key economic data for Chile.

Table A1: Economic indicators for Chile in 2019

Indicator	Data for Chile (2019)
Population size (millions)*	19.5
Land area (km^2) (continental / incl. Antarctic territory)	756,102 / 2 million
Population density (number of inhabitants per km^2)**	25
Gross Domestic Product (GDP) (billions of U.S. dollars)	289
GDP per capita (USD / per capita)	15,126
Public debt / GDP	68%
Gross domestic savings as a % of GDP	19%
Most relevant economic sectors (% GDP)	Services: 39%* Mining: 13%** Industry: 12%***
Unemployment rate (% of labour force)	7.2%
Gini coefficient (between 0=complete equality and 1=complete inequality)	0.49
Competitiveness Index (score out of 100)	70.5
Human Development Index (HDI)	0.85
Energy dependence (net import / gross available energy)	91%
Primary energy per capita (GJ/p.c.), 2018	92

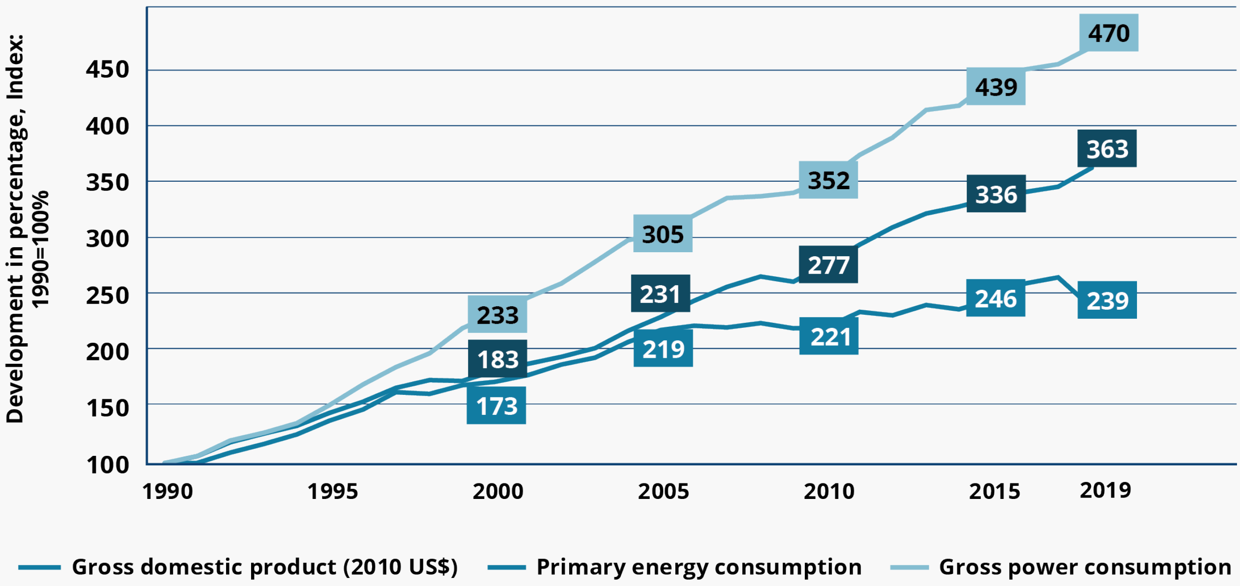
INE (2019), Central Bank of Chile (2020), WEF (2019), The Global Economy (2020), Ministry of Energy (2019)
*Includes Antarctic continent.
**Value considers the total population and the continental territory.
***Value reported in 2018.

1.2 Energy system

Chile's former state-run power sector was broken up and privatized in the 1980s. This highly successful reform subsequently served as a model for privatization initiatives in Latin America and around the world. Between 1990 and 2018, market liberalization and increasing exports led the GDP to grow by 360 per cent. While primary energy consumption grew at a slightly more restrained pace (270 per cent), electricity consumption expanded enormously, by 460 per cent (see Figure A1). Due to Chile's dependency on energy imports, the country has suffered from exposure to fluctuations in international commodity prices. Chile's primary energy consumption per annum is 1,184 PJ (2019); the main demand sectors are transport (30%), industry (26%), mining (18%), and residential (16%)[1]. Electricity generation accounts for 51 per cent of the total primary energy consumption (CNE, 2021). The electricity market is divided into:

- → **Generation:** Activities to produce electrical energy, from both conventional and renewable sources.
- → **Transmission:** Activities to transmit power at high voltage to all areas of the electrical system.
- → **Distribution:** Activities to distribute power at lower voltage levels to end-users.

Figure A1:
GDP, primary energy consumption, and gross electricity consumption in Chile, 1990–2019
(1990=100%)



Central Bank of Chile (2020), CNE (2018)

1 The other major demand areas are the commercial (6%), self-production (2%), and public (1%) sectors.

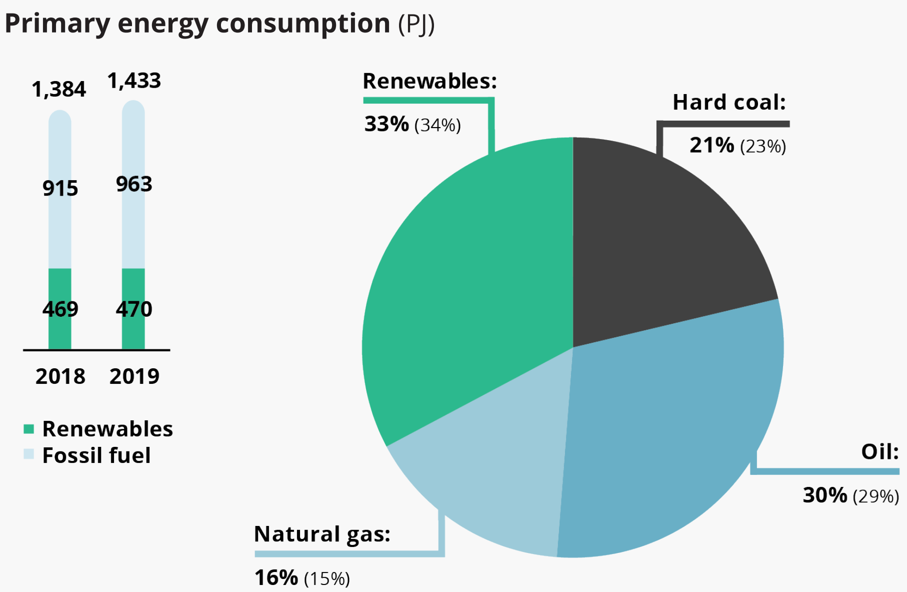
In Chile's liberalized power sector, transmission and distribution grid operations are regulated as natural monopolies. Historically, Chile had four geographically distinct grid areas. In 2017, the northern and central grid areas were interlinked, creating the National Electric System (SEN). This was a major step in addressing the geographic divergence between the complementary renewable energy generation potential and power demand centres of the industrial north and the populated central region of Chile.

Electricity consumption represents 23 per cent of Chile's total energy consumption, which is higher than the OECD average (namely, 22%). At the same time, per capita annual demand, standing at 4 MWh, is half the 8 MWh average for OECD countries, illustrating Chile's relatively lower level of economic development. By way of comparison, Slovakia and Portugal have a similar level of per capita demand (Jimenez, 2018).

Today, the unified national grid SEN has an installed capacity of 24.7 GW, which represents 99.4 per cent of the total installed capacity in the country (CNE, 2021). Annual electricity production in 2020 was 77,7 TWh. Coal, natural gas, and LNG represent 52 per cent of the electricity mix (CNE, 2021; see Figure A3), which illustrates Chile's strong dependence on commodity imports. This dependence is expected to fall over time as new renewable plants come online and coal units are shut down.

Between 2017 and 2019, Chile reduced its greenhouse gas emissions (GHG) by almost 19 per cent, primarily thanks to the transformation of its energy sector and higher efficiency in industry and buildings. The most significant reductions were achieved in the residential (64%), industry (36%), and transport (18%) sectors due to government energy-efficiency programs. However, over the same period, the public, commercial, and mining sectors witnessed a four per cent increase in GHG emissions (see Figure A4).

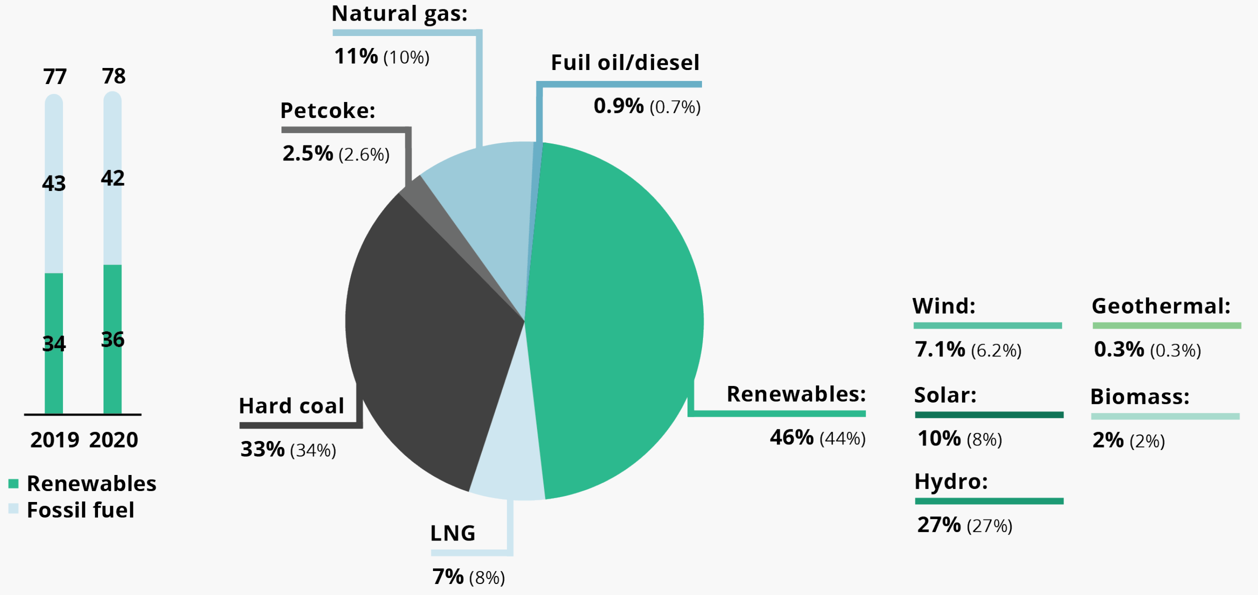
Figure A2:
Primary energy consumption of Chile in 2019 (values for 2018 in brackets)



CNE (2020)

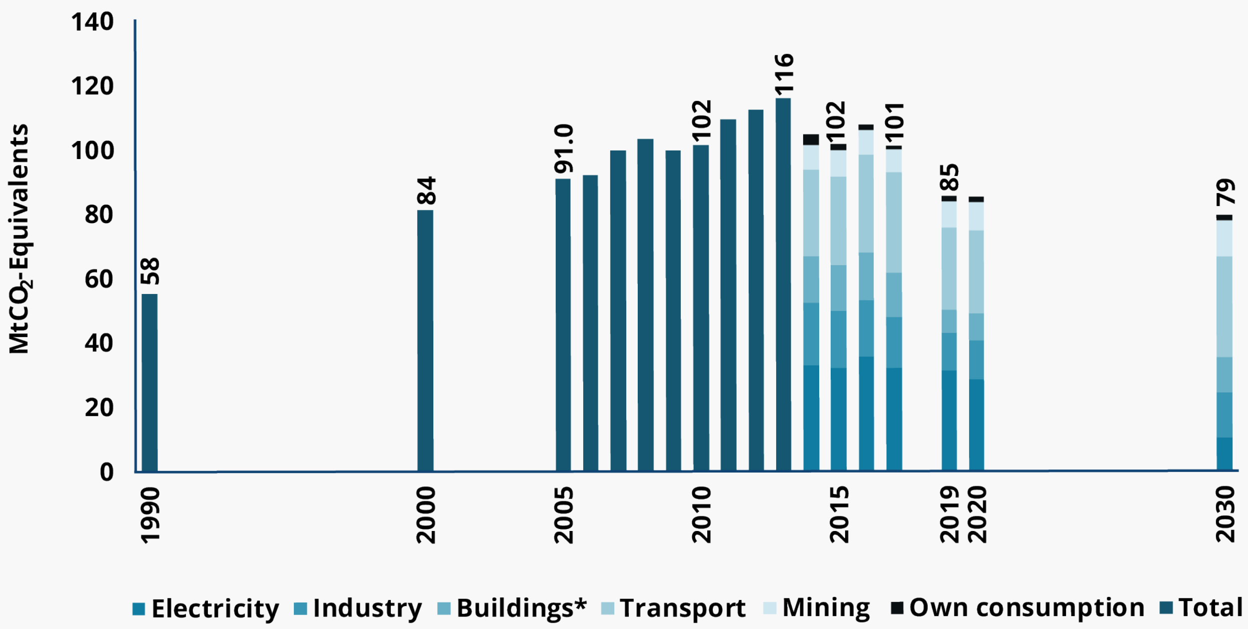
Figure A3:
Electricity mix in Chile in 2020 (values from 2019 in brackets)

Gross power production (TWh)



CNE (2021a)

Figure A4:
Chile greenhouse gas emissions by sector, 1990–2020, and target for 2030



Inventario Nacional de Gases de Efecto Invernadero (Environmental Ministry of Chile, 2018). Data after 2016 calculated by the authors based on the projected fuel consumptions reported in Planificación Energética de Largo Plazo, Chile's long-term energy planning process.

*Buildings consists of the residential, commercial, and public sectors.

1.3 Power market design

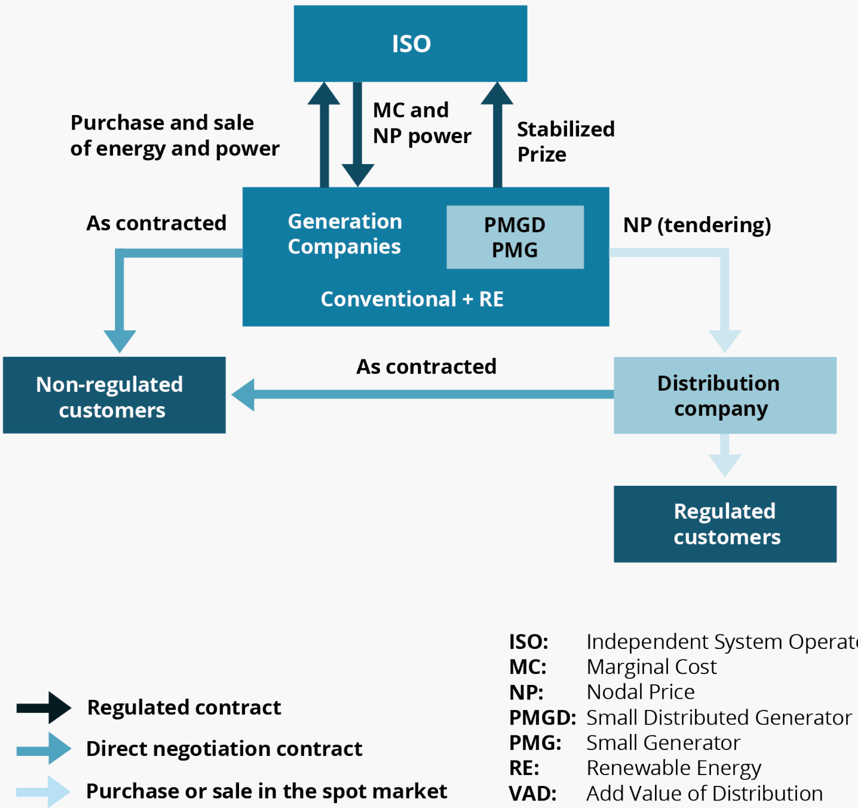
Like Germany, Chile manages its power sector based on the merit-order principle. This means that the "least marginal cost" underlies power dispatch decisions and end-customer price formation. The electricity market is a mandatory pool-type market with audited generation costs, and a wholesale (hourly) spot market restricted to generators. The interactions between market actors are presented in Figure A5 and described by the National Energy Commission (CNE, 2018).

As shown in Figure A5, the electricity market in Chile considers two types of customers:

→ **Regulated customers:** (e.g. residential customers) are end-users with a connected load equal to or lower than 5 MW. The tariff for regulated customers, which is defined by the regulatory authority, is calculated based on the costs incurred by an ideal distribution company that operates efficiently, in addition to the distribution company's purchase price. Energy auctions are an additional aspect of the system, where distribution companies arrange supply contracts with generators. In this market, generation company sales are made to distribution companies, which purchase energy at nodal prices" (see Figure A7). However, distribution companies that have a regulated power purchase agreement (PPA) with a generation company buy at the prices set in that agreement. The nodal prices are defined by the National Energy Commission (CNE), based on marginal cost projections.

→ **Non-regulated customers:** In the case of supply to end-users whose connected load exceeds 5 MW, the law foresees free price formation. The rationale is that the customer is in a better position to negotiate its own supply contracts or obtain supply in other ways, such as self-generation.

Figure A5:
Interrelationships between actors in the Chilean power market



ISO: Independent System Operator
MC: Marginal Cost
NP: Nodal Price
PMGD: Small Distributed Generator
PMG: Small Generator
RE: Renewable Energy
VAD: Add Value of Distribution

CNE (2018)

The National Electric Coordinator (CEN) is an organization that manages dispatch based on the marginal cost information provided by generation companies. This system produces an hourly dispatch price in strict accordance with the merit order (based on variable operational costs), which determines the commercial exchanges between companies.

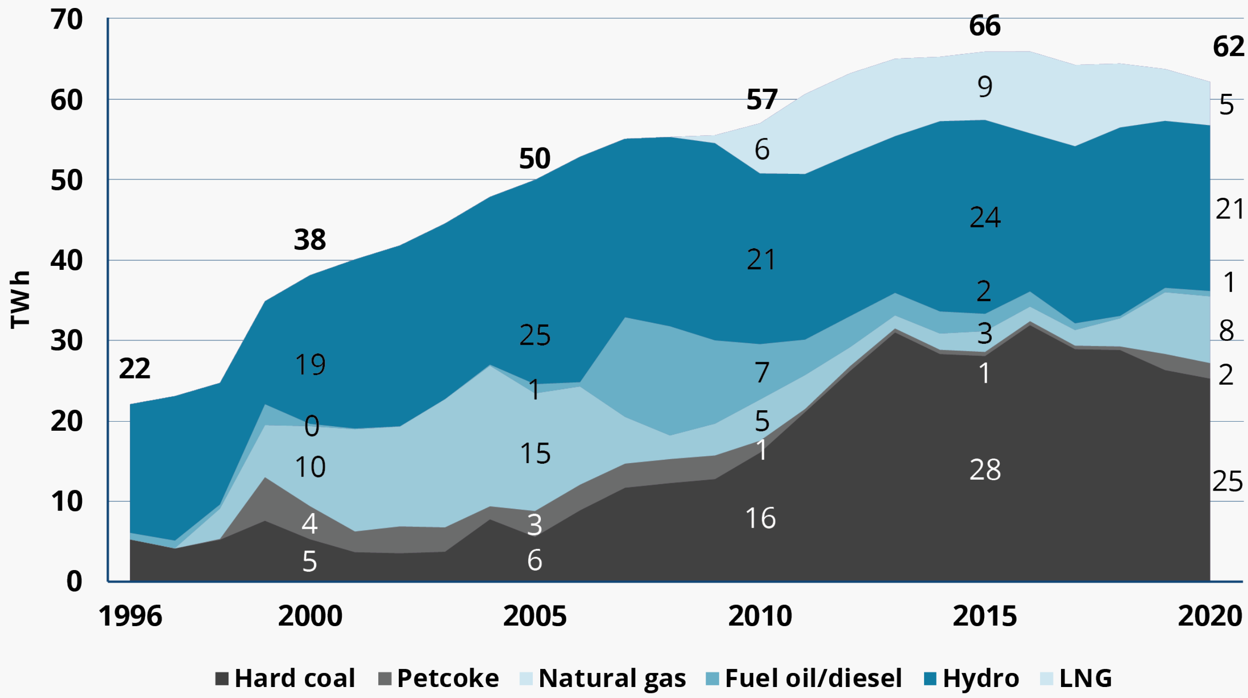
In Chile, there are no specific tax provisions for the power sector. Rather, generation, transmission, and distribution companies are subject to general corporate income tax, and the supply of energy is subject to a general value-added tax (VAT) of 19 per cent. However, a carbon tax, which currently stands at 5 USD per tonne of CO_2, was established in 2016. The tax applies to large emitters of greenhouse gases, including operations that produce more than 100 tonnes of particulate material (PM) annually. However, the environmental effects of environmental taxes are not considered in the marginal cost calculations that determine the merit order (as they are in Germany). These taxes are paid by generation companies to the Chilean tax service, and the pass-through of these taxes to customers must be approved on a case-by-case basis. In contradistinction to Germany, the Chilean electricity market does not offer direct subsidies for renewable energy projects. However, there are different mechanisms that promote renewable energy, including a tender system for renewable projects on public lands; a policy that encourages small and distributed generation; and the so-called Law 20/25 (an initiative for achieving a share of 20% renewables by 2025). While these measures seek to encourage renewables, Chile has generally remained committed to market-driven energy developments.

Historically, central Chile has relied on hydropower, while northern Chile has relied on coal. However, rapid economic growth after 1990 made it necessary to tap new sources of energy. Gas pipelines were subsequently developed to allow natural gas imports from Argentina (OGJ, 1997). Power generation costs fell 20 per cent after these pipelines were completed in 1997, a great boom for the energy-intensive mining operations connected to the northern grid. The competitiveness of natural gas accelerated the development of natural gas fired thermoelectric projects (see Figure A6) (Vargas, 2003). However, in 2004 Argentina faced domestic gas shortages, and decided to limit gas exports to Chile, thus causing power supply bottlenecks, as exemplified by the blackout of March 2005, which stretched over 1,000 km of the country (from Copiapó to Talca). A few years later, in 2008, Argentina completely suspended natural gas exports to Chile, triggering an energy crisis. The following actions were taken in response:

- → **Chile converted natural gas power plants to diesel,** despite the resulting high costs and output decline of 14 per cent;
- → **All coal-fired plants were operated at maximum output,** despite efficiency losses and significantly higher wear and tear, and projects on new coal plants were initiated;
- → **Construction began on two liquefied natural-gas (LNG) terminals,** to diversify energy imports; and
- → **A national energy savings campaign was initiated,** the impact of which can be seen in Figure A6.

During the natural gas supply crisis, Chile also experienced a second year of drought, which was associated with a 34 per cent reduction in reservoir levels, thus reducing hydroelectric output (see Figure A6) (Barañao, 2008). As a result of these developments, electricity prices increased from below 60 USD per MWh prior to 2005 to as high as 140 USD per MWh in 2008–09, as shown in Figure A7.

Figure A6:
Gross power production from conventional energy sources in Chile, 1996–2020



1997 – Gas pipeline between Argentina–Chile completed;
2004 – Gas crisis in Argentina; 2008 – Gas supply cut to Chile
CNE (2021a)

Because prices remained above 100 USD per MWh for an extended period with no indication of returning to their previous levels, the mining sector in the north undertook several projects to ensure future energy supplies.
As mentioned, existing gas fired power plants were converted to diesel; backup diesel units were installed on a large scale to handle demand peaks. As a consequence, diesel became a dominant energy source, supplying 23 per cent of power generation.

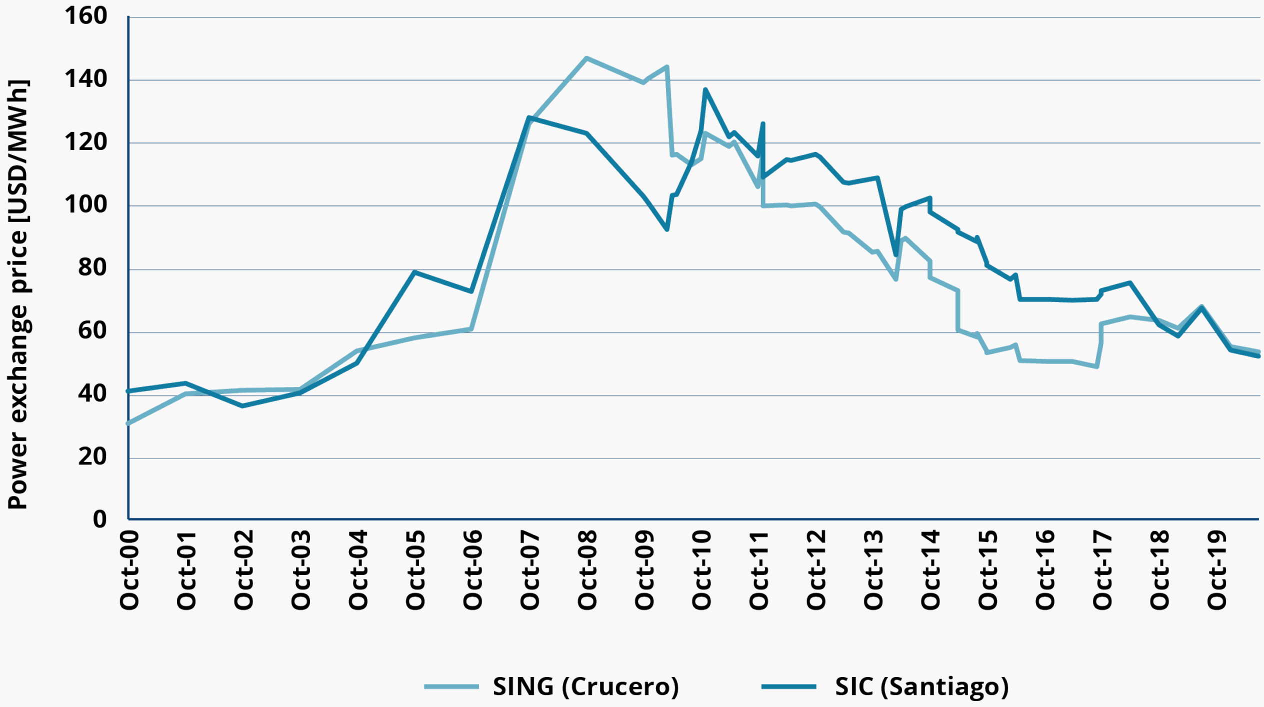
At the same time, work began on developing new coal-fired power plants, constructing LNG terminals, and expanding renewables, biomass, and wind. In 2008, renewable energy was still relatively expensive, and the only relevant investment support was the international Clean Development Mechanism (CDM)[2]. At the time, coal development did not face environmental restrictions or public opposition. It also represented the most cost-effective and reliable method of expanding power supplies.

After 2015, following the completion of these new coal plants, renewables became much cheaper. Wind and solar subsequently experienced rapid expansion, which reduced power prices and emission factors, as shown in Figure A8.

1.4 Coal mining

While Chile has operated coal mines for over 150 years, domestic production fell to negligible levels by 1997 due to cheap imports. Accordingly, coal mining is not a relevant aspect of the current discussion on exiting coal. However, Chile's historical exit from coal mining is relevant for the current context, and is thus summarized in the infobox below.

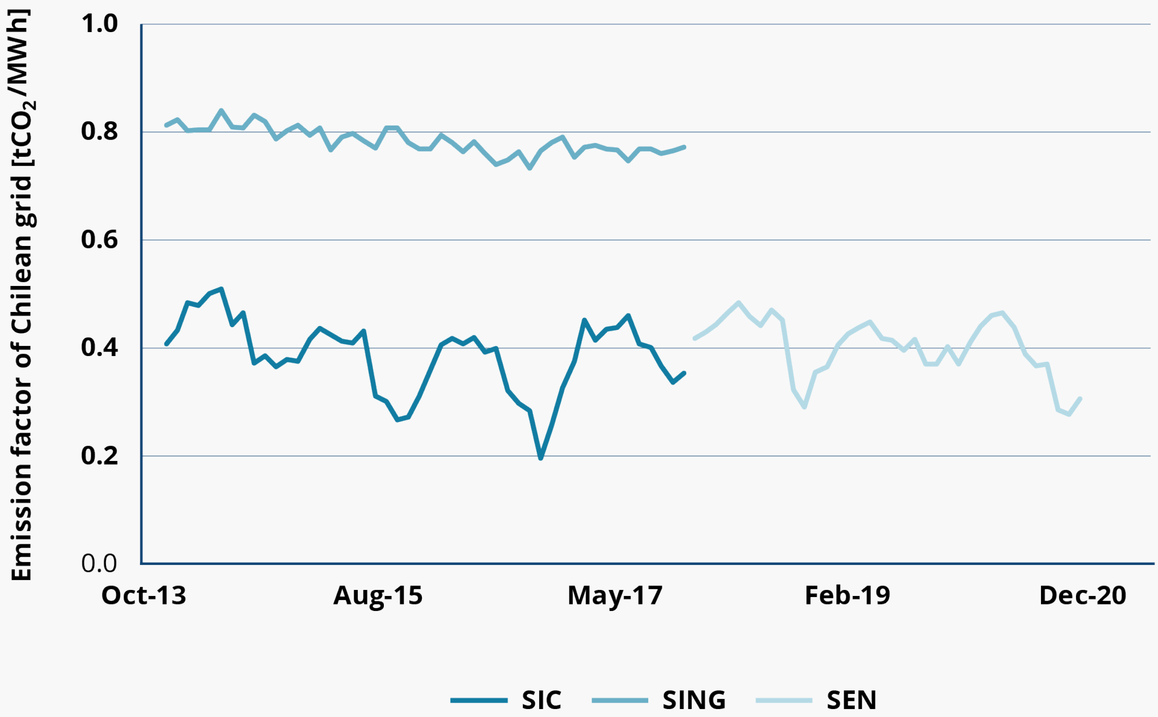
Figure A7:
Electricity nodal prices in Chile, 2000–2020



CNE (2021c)

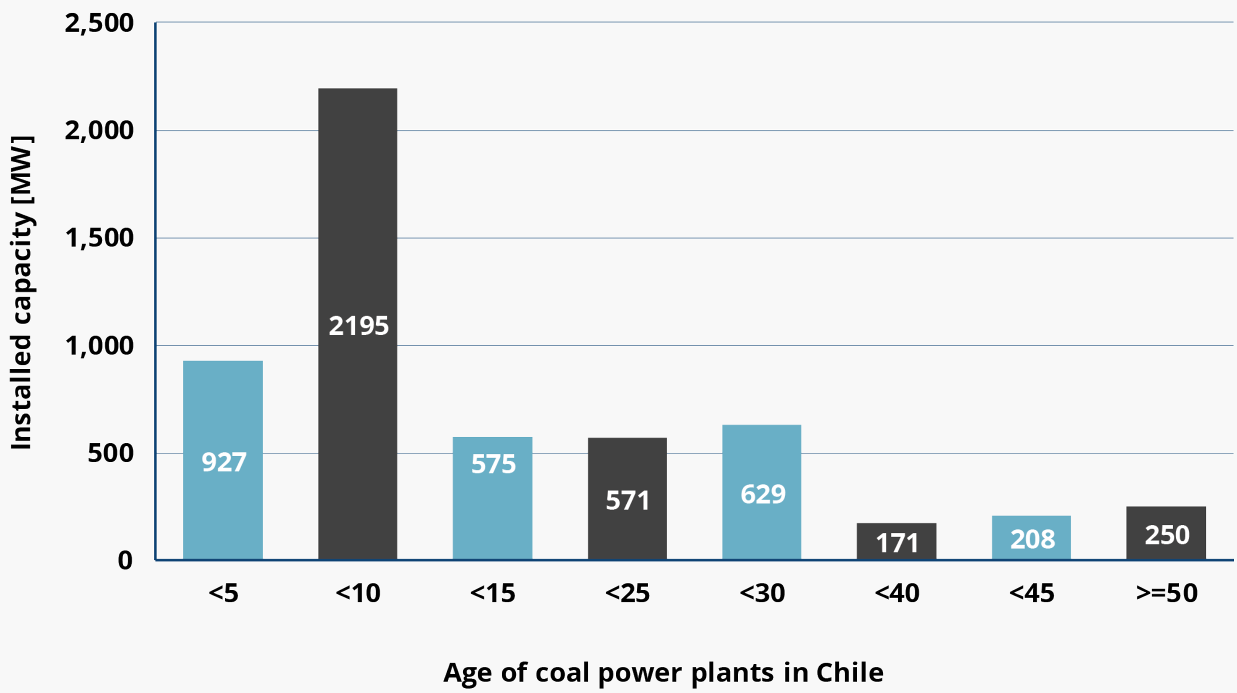
Accordingly, substantial investments in coal power were made between 2008 and 2019. A total of 15 coal-fired plants were built, equivalent to 3.7 GW of capacity. Plants commissioned in the last 15 years now represent 71 per cent of Chile's installed coal capacity. Before initiating the formal process for exiting coal power, Chile had 28 coal-fired units, the oldest of which had been in operation for 56 years (see Figure A9).

Figure A8:
Grid emission factors in Chile, 2013–2020



CNE (2021c)

Figure A9:
Coal plants by age before the coal phase-out commission



CNE (2021a), Colbun (2019), Enel (2019), AES Gener (2018)

A brief history of Chilean coal

Coal mining began in the mid-1800s and soon made Chile an important refuelling station for coal-powered ships undertaking the “East–West passage” through the Straights of Magellan. However, the country lost its relevance as a stopover point in international shipping after the opening of the Panama Canal, in 1914. An additional blow to Chile’s role in international trade was the German development of a technique for synthesizing ammonia and nitrates (an important ingredient in fertilizers and explosives) during the First World War, which destroyed the hugely important saltpeter mining industry.

Coal was the lifeblood of numerous sectors, including the railroad, power utility, steel refining, and copper mining industries. Various commercial activities also sprung up around the coal mines, including glass, brick, and lumber factories, in part to supply the mines themselves (Enacar; Biblioteca Nacional de Chile; Jáuregui). Beginning in the 1970s, coal entered a period of sustained crisis, as domestic coal production became uncompetitive internationally. As a result, coal was increasingly supplanted as a fuel source by cheap oil and natural gas imports. Following massive layoffs in the coal-mining sector in the 1990s, extensive government support was provided for winding down coal operations, for retraining and relocating workers, and for funding early retirement schemes.

Many Chilean economists were critical of this expensive government intervention, not only as a violation of free-market principles, but also because the costs ultimately seemed to outweigh the benefits; retraining measures were less successful than initially hoped. Thus, despite government efforts to ease restructuring, the closing of mine operations triggered isolated instances of worker unrest, culminating in concessions to labour and the preservation of some mining activities.

Today, Chile no longer operates coal mines. The last mine, Mina Invierno, closed in 2020 after losing its blasting permit. Its production levels had already been low from an international perspective. According to the Servicio Nacional de Geologia y Mineria (2020), it produced around 2 million tonnes (Mt) annually in 2019, versus 200 Mt in Germany and 3.8 billion tonnes in China.

2. Driving forces for energy transition and coal phase-out

2.1 Overview of the energy transition

While Chile expanded its dependence on coal in response to the energy crisis of 2007, a political movement to adopt renewables and phase out coal power gathered momentum in subsequent years. Chile is a signatory to the Paris agreement, and has taken concrete regulatory and tax policy steps to encourage the sustainable transformation of energy systems.

Popular political pressure has been an important component of this process. An historic milestone was the resistance in 2010 to the Barrancones coal power plant, which ultimately led to the abandonment of the project (El Mercurio, 2010).

The Barrancones episode galvanized public and environmental NGO resistance to the construction of additional coal power plants. The resulting political pressure has encouraged the private sector to reconsider coal-related projects.

2.2 New taxes and standards

Coal-fired power production has become less competitive due to new taxes and environmental standards:

- → **Special taxes:** In 2018 Chile adopted special taxes on greenhouse gases and airborne pollutants (CO2, SO2, NOX, and particulate matter). In particular, a carbon tax of 5 USD per tonne was enacted for emissions from fixed sources.[3]
- → **Social cost of carbon dioxide:** In 2017, new rules for public investment projects were enacted, requiring 40 USD per tonne to be used as a basis for assessing the "social cost" of emissions. According to experts, this sent a clear signal to coal power companies that near-term government action could dramatically increase their cost of doing business.
- → **Emission standards:** In 2011, the Chilean environmental ministry established caps for the first time on power plant emissions of mercury (Hg), particulates (PM), sulfur dioxide (SO2), and nitrogen oxide (NOX). Furthermore, these caps are set to become more stringent over time, thus forcing power plant operators to evaluate abatement technologies, alternate fuel sources, or full decommissioning.

2.3 Renewables feed-in obligation

In 2013, the adoption of the Law 20/25 established a renewables quota, fuelling a massive expansion of solar and wind capacity in the north of Chile. Government subsidies were not required to stimulate investment, as used in many countries, given Chile's excellent wind and solar resources in combination with the general technology cost declines that had been achieved in prior years. The expansion of so-called non-conventional renewable energies (NCRE) ultimately led power prices to decline some 40 per cent from their pre-2014 highs. Lower power prices have forced coal power plants to operate at low load levels or in intermittent cycles due to their high marginal costs in relation to renewables.

3 This figure was used because it was the average trading value from for CDM carbon credits (information provided by Marcelo Mena, former Minister of Environment 2017).

2.4 Key factors impacting coal power

The following factors are anticipated to encourage the phase-out of coal in the coming years:

- → Chile's excellent endowment of natural resources for renewables production.
- → Fear of a rise in the CO_2 tax.
- → Increasingly, the mining sector is demanding renewable energy.
- → Numerous banks and insurance companies have objected to taking on coal projects, due to financial and reputational risks[4] in view of the general international momentum to phase out coal.
- → More stringent emissions standards will cause coal plants to have higher investment and operating costs.
- → Increasingly, economists are including potential commodity price fluctuations in their estimate of conventional energy project risks, nudging investment decisions in favour of renewables.
- → Chile has introduced a mechanism for placing coal power plants in a back-up reserve. According to the amended Supreme Decree 42, power plants with Strategic Reserve Status (Estado de Reserva Estratégica, ERE) receive compensatory payments for five years (Ministry of Energy, 2020b).
- → Regulatory changes like the new flexibility strategy aim at encouraging greater flexibility in the power grid, which is likely to make coal power less competitive (Ministry of Energy, 2020a).
- → The COVID-19 pandemic has reduced power demand while freeing up supply, further harming the profitability of coal. It remains to be seen whether this most recent strain to the coal power sector will lead additional plants to shut down for economic reasons.

4 JPMorgan Chase, for example, has adopted an environmental and social policy that prohibits involvement in the coal industry. Numerous insurance companies, including Allianz, Swiss Re, and Lloyd's, adopted similar policies in 2017.

3. The Chilean coal commission

3.1 Establishment of the coal commission

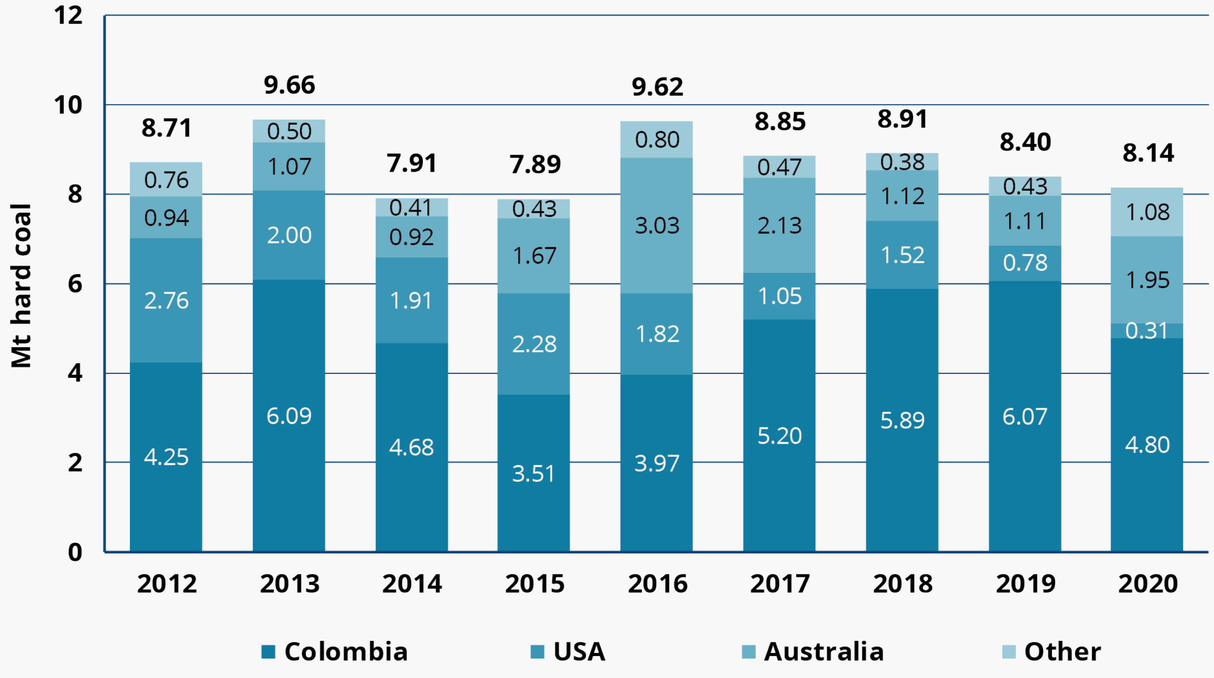
In 2017, the federal government adopted the Climate Action Plan 2017–2022, which strengthened emission standards while establishing mandatory energy-efficiency measures for coal power plants.

Subsequently, in January 2018, Chile inaugurated a formal process for decarbonizing its energy system with an agreement between the Ministry of Energy and Environment; coal power companies (Enel, AES Gener, Engie, and Colbún); and the Chilean Association of Power Generators (AGC) (Peña, 2018)[5]. The agreement comprised three elements:

- **Agreement 1:** Cease development of new coal projects that do not have carbon capture and storage (CCS) or equivalent abatement technologies.
- **Agreement 2:** Create a working group to analyse the technological, environmental, social, economic, and energy security aspects of a coal exit strategy, with a view to each plant and the electricity system. The working group was tasked with identifying a schedule and associated conditions for the managed and gradual shutdown of coal-fired plants that do not have CCS or other equivalent abatement technologies.
- **Agreement 3:** The Ministry of Energy was nominated to coordinate the working group, which was to represent all stakeholders.

However, as part of this initial agreement, no date was set for the final phase-out of coal power. In May 2018, the Energy Roadmap 2018–2022 was published (Ministry

Figure A10:
Origin of hard-coal imports to Chile



Own elaboration based on data from Aduana (2016, 2020)

5 In the run up to the agreement and in preparation for COP23, a consensus was reached that Chile would not join the international Powering Past Coal Alliance (PPCA); this was a concession made to get industry support (information provided by Marcelo Mena, former Minister of Environment 2017).

of Energy, 2018), which proposed working along seven axes (see Figure A11) to achieve ten commitments. Five of these commitments related to the decarbonization of the energy system:

- → **Commitment 4:** Expand small-scale distributed renewable generation systems under 300 kW by a factor of four by 2022.
- → **Commitment 5:** Increase by at least 10 times the number of electric vehicles in the national fleet.
- → **Commitment 6:** Make power sector regulations modern and efficient while considering new practical realities.
- → **Commitment 7:** Establish a regulatory framework that encourages energy efficiency.
- → **Commitment 8:** Initiate decarbonization through the elaboration of a schedule for the withdrawal or conversion of coal-fired plants, and for measures to expand electric vehicles.

Based on Agreement 3 and Commitment 9 of the strategy, in June 2018 the Ministry of Energy developed a technical and interdisciplinary coal commission to evaluate the social, economic, and environmental effects of the phase-out and/or conversion of coal-fired plants. This commission undertook the first rigorous evaluation of the conversion or replacement of coal units to renewable alternatives in terms of socioeconomic and labour market impacts

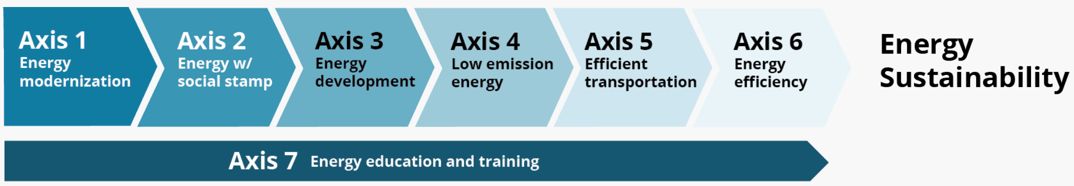
3.2 Stakeholder composition

With the objective of establishing a representative group of stakeholders, the coal commission included: the four companies operating coal plants; three public institutions; one industry association, three consumer associations; two academics; three NGOs; three civil society associations; one municipality; one international agency; and the national electrical coordinator, as summarized in Table A2.

Other organizations were invited to present on relevant topics:

- → **Human health effects of coal power:** University of the Andes, University of Chile, and the Environmental Ministry.
- → **International phase-out experience:** Agora Energiewende; UK Department for Business, Energy and Industrial Strategy; the International Energy Agency (IEA); and the Sierra Club.
- → **Decarbonization impacts on the power system:** The National Electrical Coordinator, the Energy Center of the University of Chile, the Geothermic Council, Valgesta Energy, and ACERA.
- → **Environmental factors:** INODÚ, Municipality of Coronel, Aria Technologies, CR2 Group (University of Chile), and CLG Chile. [6]
- → **Technology alternatives:** INODÚ/GIZ, E3G, and Enel Energy Transition.
- → **Economic and social impacts:** The Interamerican Development Bank, Consultor, and the International Labour Organization (ILO).

Figure A11:
Working axis of the Chilean Energy Road Map 2018-2022



Ministry of Energy (2019)

6 **The CLB is an association of Chilean Business leaders against climate change.**

3.3 Function and mandate

The commission was tasked with evaluating the effects of the coal phase-out and the associated conversion or replacement of coal facilities. The Ministry of Energy, which chaired the commission, emphasized that deliberations would need to consider the safety and efficiency of the power system as well as local economic impacts. The Ministry of Energy set the goal of agreeing to a timeline for a phase-out and the associated conditions by the first half of 2019.

GIZ participated in the meetings of the Chilean coal commission as a permanent international representative.

GIZ provided scientific and technical expertise on a range of issues[7], including the productive use of solar energy in the north of Chile, the environmental impacts and health consequences of Chilean coal power, and the technical options for reconverting the coal-fired power plants. The German think tank Agora Energiewende also shared insights regarding the German decision to phase out coal and provided a technical analysis of alternatives for reconverting existing coal-fired power plants.

Table A2: Members of the coal commission

Category	Institutions	Category	Institutions
Power sector companies:	Engie, ENEL, AES Gener, Colbún	NGOs:	WWF Chile, Casa de la Paz, Sustainable Chile
Public sector:	Ministry of Energy, National Energy Commission, Ministry of Environment	Civil society:	Central Coal Workers Union, Civil Society Council of the Ministry of Energy
Industry associations:	Chilean Association of Generators (AGC)	Municipalities:	Municipalities of Tocopilla and Coronel
Consumers:	Mining Council, Association of Non-regulated Energy Customers (ACENOR), Consumer and User Organization (ODECU)	International organizations:	GIZ (Gesellschaft für Internationale Zusammenarbeit [German International cooperation agency])
Academia:	Pontific Catholic University, Adolfo Ibañez University	Independent institutions:	National Electrical Coordinator

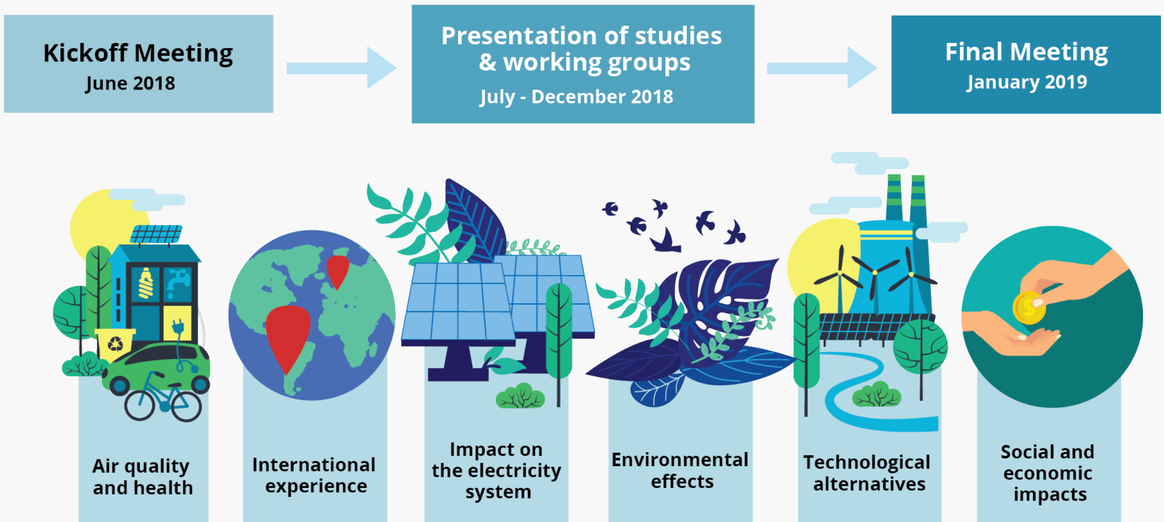
Ministry of Energy (2019)

7 For more information on the expertise and studies that contributed to the discussion, see the GIZ website https://www.4echile.cl/proyectos/descarbonizacion/.

3.4 Timeline and operational aspects

The coal commission held nine working sessions between June 2018 and January 2019 (see Figure A12). Five studies were performed to analyse social, environmental, and economic aspects of a phase-out.[8] In addition, 28 national and international experts were invited to present their work.

Figure A12:
Timeline and structure of committee meetings



Inodú (2019)

8 The study subjects were: (1) expectable impacts to the national power system; (2) insights from the UK coal phase-out; (3) environmental and social variables; (4) impacts on local economy and jobs; and (5) options for converting coal plants to renewables.

4. Findings and recommendations of the coal commission

4.1 Coal phase-out plan

The findings of the coal commission were used to determine a schedule for the phase-out of coal-fired plants in a manner sensitive to social, environmental, and economic factors. In the months following the commission's final report, the government and five private companies hammered out a schedule for the phase-out, which was presented by the president in June 2019 (see Table A3). The schedule called for the closure of eight plants within five years, representing 19 per cent of installed coal power capacity. Private-sector compliance with the decarbonization schedule was made contingent on the government's amendment of the Regulation of Power Transfer between Generating Companies (including the creation of a new operating status known as Strategic Reserve Status, which provides for government support payments) (Ministry of Energy, 2020b).

Under the schedule, the closure of coal-fired power plants was to take place in two phases. The first phase originally foresaw the exit of 8 units by 2024 (equivalent to 1 GW of installed capacity). The second phase involved the closure of the remaining coal-fired units in the country by 2040 at the latest.

Ultimately, the schedule adopted in June 2019 did not set forth closure dates for 17 coal-fired units (equivalent to 3,788 MW of capacity), due to various considerations, including the legal obligations of generators and grid stability concerns.

In December 2019, in the context of the COP25 Chile/Madrid, a further agreement was reached between the government and generating companies for the early closure of two coal-fired plants (CNE, 2019). Subsequently, in May 2020, following pressure from environmental groups, ENEL announced the early closure of the coal power units Bocamina I for December 2020 and Bocamina II for May 2022 (see Table A3).

In May 2021, Engie announced that it would retire its full fleet of coal-fired plants by 2025. As a result, 50%

Table A3: Coal-fired power plants phase-out schedule

Coal power plant	Company	Power	Entry into	Phase-out date	
		[MW]	Service	Original	Updated
Unit 12	Engie	85	1983	June 2019	Closed
Unit 13	Engie	86	1985	June 2019	Closed
Tarapacá	Enel	158	1999	May 2020	Closed
Unit 1 Ventanas	Aes Gener	114	1964	November 2022	Closed in December 2020
Bocamina Unit 1	Enel	128	1969	December 2022	Closed in December 2020
Unit 14	Engie	136	1987	May 2024	January 2022
Unit 15	Engie	132	1989	May 2024	January 2022
Unit 2 Ventanas	Aes Gener	204	1977	May 2024	Until 2022
CTM 1 & 2	Engie	334	1994	Until 2040	December 2024
Bocamina Unit 2	Enel	350	2011	Until 2040	May 2022
CTA	Engie	177	2011	No closing date	By end of 2025
CTH	Engie	178	2011	No closing date	By end of 2025
IEM1	Engie	377	2019	No closing date	By end of 2025

Energy Ministry (2019a), CNE (2019), La Tercera (2018), Chilean Government (2018, 2019, 2020) of Chile's coal-fired units will be retired or converted by 2025. This is 19 percentage points greater than the 31% described in the original schedule from 2019. Engie plans to convert its youngest plants (i.e. those built after 2010) to natural gas or biomass.

4.2 Grid adaptation measures

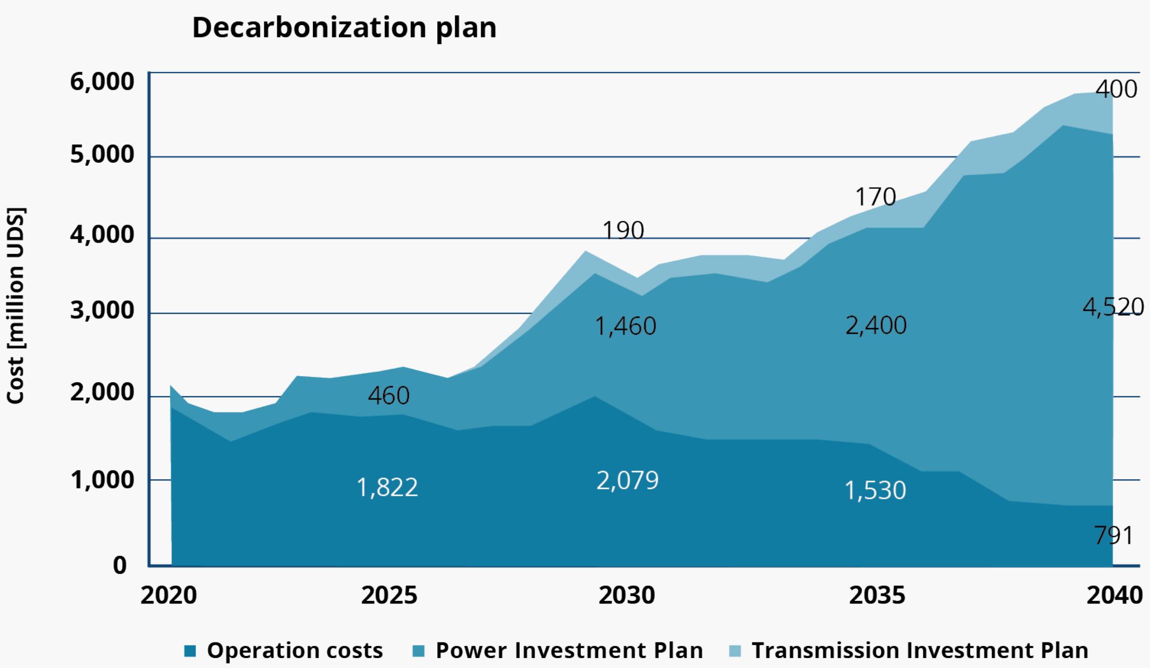
In session 5, the National Electric Coordinator (CEN) proposed a schedule to phase out coal power plants, considering a 20-year horizon. The study concludes that the phase-out of coal-based power plants requires the creation of a new power and transmission infrastructure that maintains the security of supply requirements. This new infrastructure will involve additional investment costs for the electricity sector. These are associated in part with new power plants, needed to make up for lost coal generation, and the expansion of transmission lines. Among other things, the study recommended the installation of 4 GW of transmission lines. The phase-out of coal power is estimated to generate 20 billion USD in additional grid expenses up to 2040 versus a scenario without plant closures (see Figure A13). However, the additional expenses are likely to be partially offset by the lower operating costs of renewables relative to coal (see Figure A13). Although the decarbonization plan leads to more costs, it results in long-term positive effects in terms of reduced external costs with regard to mortality, morbidity, and job creation (see section 4.4).

4.3 Technological conversion options

The coal commission evaluated several mature technological alternatives for retrofitting coal power plants. These are summarized in Table A4. Reference investment costs are between 50 and 231 USD per kW for natural gas conversion and between 473 and 1,212 USD per kW for biomass conversion (Inodú/GIZ, 2018). However, some of the conversion options are not viable, and others require regulatory changes. In addition, such investment outlays can have negative merit-order effects, posing profitability risks.

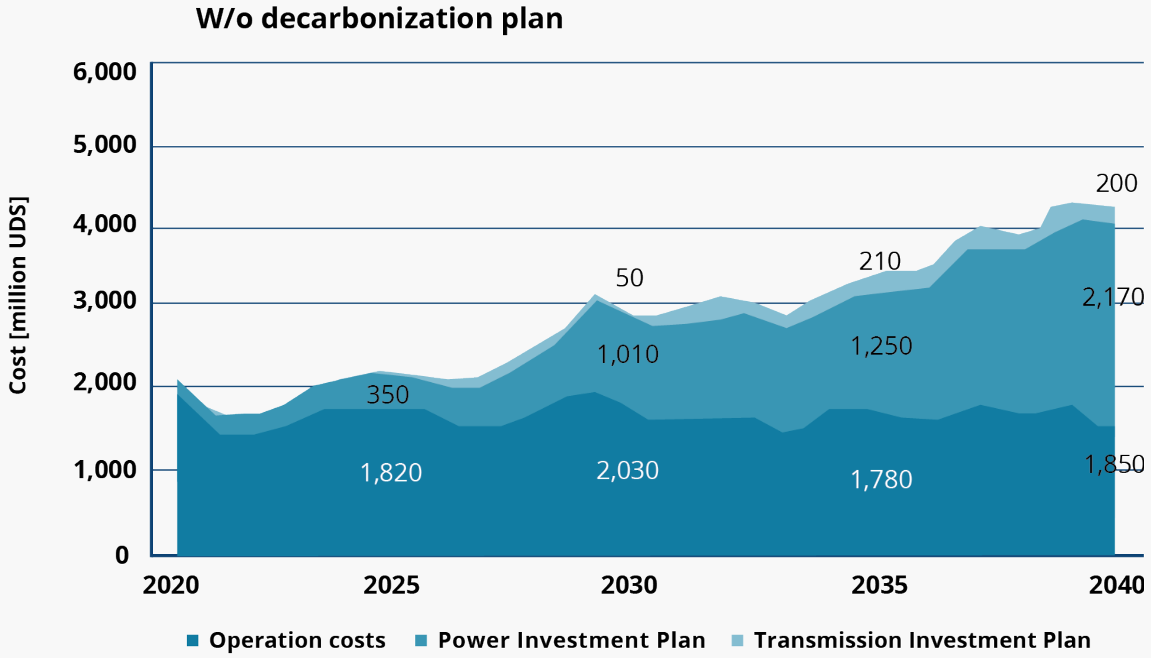
Cheap domestic natural gas has enabled coal to natural gas conversion in the United States. In the UK and Netherlands, by contrast, there are various examples of biomass conversion. In Chile, conversion decisions will hinge on fuel costs. The use of natural gas is

Figure A13 i:
The cost effects of the phase-out of coal power plants on the electrical system



National Electric Coordinator (2018)

Figure A13 ii:



National Electric Coordinator (2018)

generally more economical, feasible, and scalable, and enables more flexible plant operation. The alternative of reconverting coal-fired power plants with thermal storage systems run on renewables is being investigated in Chile. The study is led by GIZ in cooperation with DLR, the energy companies AES and Engie, the system operator, and the Ministry of Energy.

The National Electric Coordinator has estimated that efficient levels of coal-fired plants conversion lie between 30 and 70 per cent of existing capacity. This means that a conversion of around 1,640 MW would be feasible in the short term. Carnot batteries and solar PV technology are regard as highly compatible (National Electric Coordinator, 2021).

4.4 Human health benefits

Between 2000 and 2010, Chile experienced a troubling increase in mortality and morbidity rates in areas close to major emission sources, such as coal units and copper smelters. The medical literature clearly shows that airborne emissions are associated with higher rates of cardiovascular disease, respiratory conditions, and cancer.

It has been estimated that the phase-out of coal plants operating in 2018 would lead to annual emission avoidance of 25 $MtCO_{2eq}$, 1.4 thousand tonnes of PM, 27 thousand tonnes of SO_2, and 31.2 thousand tonnes of NOX. In this way, the coal phase-out promises to have direct benefits in terms of improved human health.

4.5 Guidelines for managing local adaptation

The coal commission developed numerous recommendations designed to ease the transition in affected communities (Inodú, 2018):

- → Power plant operators should communicate in advance with communities impacted by closure.
- → Actors from various sectors should be invited to identify alternate site uses.
- → Municipalities should develop a programme for site adaptation, including incentives for retraining/reemployment.
- → Stakeholders should define limits of liability between the decommissioning company and legal successors that consider the future development of the site and the community.
- → An economic stimulus plan should be developed to encourage retraining and new jobs. The commission noted it may be necessary to manage expectations about job creation and the arrival of new industries.

Table A4: Technical alternatives to coal power considered by the commission

Alternatives	CO_2 emissions	Operational flexibility	Investment cost	Effect on employment
Options for partial or total conversion of the coal power plant to another fuel				
Natural gas conversion	↓↓	↑↑	50-231 [kUSD/MW]	Slight reduction
Partial conversion to natural gas	↓	↑↑	5-10 [kUSD/MW]	Neutral
Conversion to forest biomass	↓↓↓	↓	473-1,213 [kUSD/MW]	Neutral
Co-combustion of coal with natural gas	↓	↓	54 [kUSD/MW]	Neutral
Co-combustion of coal with forest biomass	↓	↑	537 [kUSD/MW]	Neutral
Options to use the power plant infrastructure				
Closure and dismantling of the plant	↓↓↓	Not applicable	36-62 [kUSD/MW]	Reduce
Strategic reserve unit	↓↓↓	Not applicable	25-33 [kUSD/MW]	Reduce
Municipal solid waste incineration	↓	↓↓↓	7,000-11,000* [kUSD/MW]	Reduce
Gas engine replacement	↓	↑↑↑	1,300 [kUSD/MW]	Reduce
Seawater desalination	Neutral	Neutral	1.2-2.8 [kUSD/MW]**	Reduce
Unit conversion options including CO_2 capture systems				
Adaptation with carbon capture system	↓↓↓	↓↓	4,308-10,135 [kUSD/MW]	Increase
Hydrogen and electricity cogeneration	↓↓↓	Unknown	2-2.3 [kUSD/MW]***	Increase
Use of infrastructure attached to the plant other than the boiler				
Short term storage system (batteries)	↓↓↓	↑↑	352-578 [kUSD/MWh]****	Reduce
Compressed air storage system	↓↓↓	↑↑↑	1,500-3,000 [kUSD/MW]	Reduce
Thermal storage system using molten salt	↓↓↓	↑↑↑	30 [kUSD/MW]	Reduce

* Estimated costs based on the conversion of pulverized coal technology to mobile grills.
** Values given integrate desalination plants in thermoelectric units. Engie's plants located in the cities of Tocopilla and Mejillones already have water desalination systems.
*** Los valores independientes de costo capital son para H2 (1.8 kUSD/MW) y para electricidad (3.0 kUSD/MW).
**** 2006 values in USD thousands/MWh. It is expected that by 2030, the battery cost will fall by 54–61%. In 2009, when the first set of batteries began operating, the average monthly marginal cost consistently exceeded 150 USD/MWh.

4.6 Ongoing process steps

The members of the coal commission unanimously agreed that more research was required to develop a successful plan to phase out coal power plants while minimizing the impacts on the electrical system and society, given that coal power is directly responsible for 4,100 permanent jobs and indirectly responsible for 9,000 others (Inodú, 2018). The Ministry of Energy was thus tasked with developing a job transition strategy based on:

- → Detailed diagnosis and quantification of the workforce that will be directly affected.
- → Characterization of the work profiles and skills of affected workers.
- → Study of potential opportunities for employment in projects that would receive investments in the short term.
- → Identification of the gaps between existing competencies and required skills for future employment.
- → Identification of new government support measures to aid local development initiatives for communities affected by power plant closures.
- → An update of health studies examining the effects of coal plants on human health, focusing on specific locations and vulnerable groups, including the impact from emission standards introduced in 2011 (Ministry of Energy, 2020a).
- → Review of Chilean NDC, considering the costs and benefits of early decarbonization (Ministry of Energy, 2020a).

The commission concluded that additional research is also needed on various topics, including:

- Zone-based transmission grid expansion requirements.
- Effects on the GHG emissions produced by cycling coal power plants.
- Costs associated with the cycling of combine-cycle gas power plants.
- Investment required to develop flexible gas power plants
- Investment requirements for natural gas infrastructure.

5. Implications for Chile's energy policy

To date, the findings of the decarbonization committee have primarily affected the technical aspects of the power system. At the same time, Chile is working on the development of mechanisms to enable the fulfilment of its international climate policy commitments.

5.1 Reception of the recommendations by political actors and key stakeholders

Stakeholder responses to the recommendations of the coal commission were diverse (Ministry of Energy, 2020c):

→ **NGOs:**
The work of the commission was generally lauded, but the lack of a binding agreement was criticized.

→ **Private sector:**
General praise, including calls to expand discussion (as described in section 4.6).

→ **Coal power workers:**
Fears were voiced that the process would occur faster than expected and that no substantive support would be provided.

→ **Government:**
The environmental ministry praised the findings as valuable for further elaborating policy.

5.2 Market developments since the publication of recommendations

A significant reduction in coal generation was observed in 2018 (see Figure A14), but this was not attributable to the decarbonization committee. The agreements reached with industry resulted in a near-term decline in coal generation, offset by generation from renewables and natural gas. As explained in 4.1, since its adoption the coal phase-out plan has been updated twice to speed up the closures of non-systemically relevant coal plants.

However, the economic turbulence and uncertainty resulting from COVID-19 has stymied discussion and concrete progress on the coal exit, in part because the pandemic has lowered power demand. As a result, there has been greater reliance on coal in the power mix (see Figure A14).

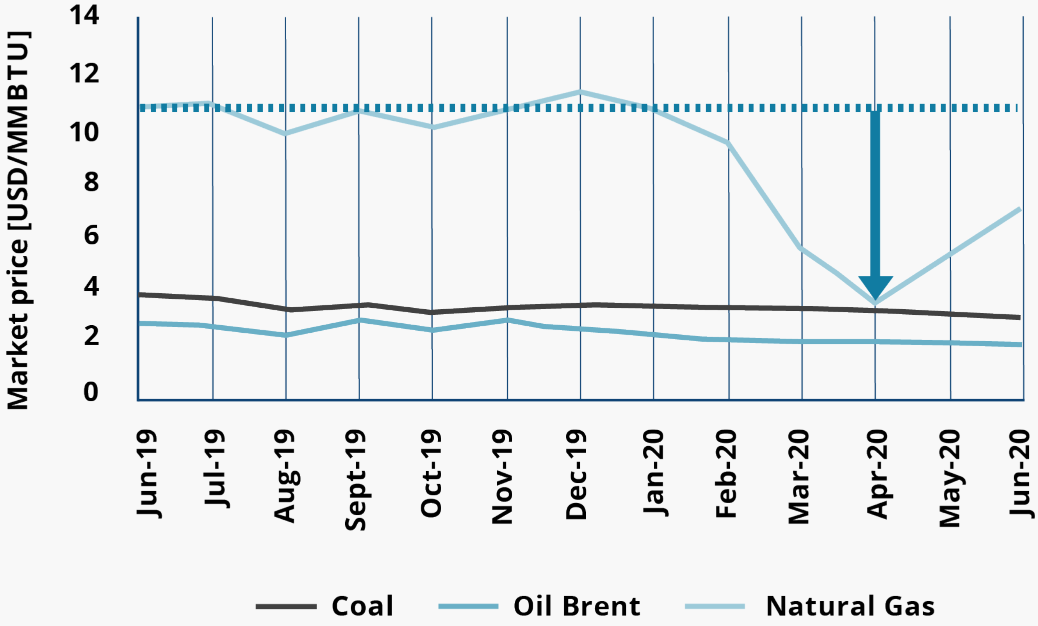
Other recent market developments bear witness to the fact that coal-fired power production has become less competitive:

→ Mining companies pay relatively high sums to leave existing GHG-intensive PPAs: BHP paid 840 million USD to AES Gener to exit a supply contract that ran until 2029 as early as August 2021. BHP will get its energy from renewable sources and AES will accelerate the closure of the coal plant (PV Magazine Latam, 2020).

→ Major power companies are working toward balance sheet carbon neutrality: AES Gener sold its shares of all five units (764 MW) in the northern coal plant in Guacolda in February 2021. The new majority stakeholder has subsequently committed to closure by 2040 in accordance with the phase-out plan. However, unless the transmission grid is expanded and more flexible, the coal-fired plants in Guacolda will remain relevant for the northern region of Chile (Energia Estrategica, 2021).

→ New financing models have appeared: IDB Invest granted a $125 million USD financial line to Engie Energía Chile, in a bid to accelerate the decarbonization of the country's electricity matrix. The loans, with a term of up to 12 years, will be used to build, operate, and maintain a wind farm near the city of Calama in the Antofagasta Region. The financial package consists of a $74 million USD senior loan from IDB Invest, $15 million USD in blended financing from the Clean Technology Fund (CTF), and $36 million USD from the China Fund for co-financing in Latin America and the Caribbean (Lex Latin, 2021).

Figure A14:
Fossil fuel prices

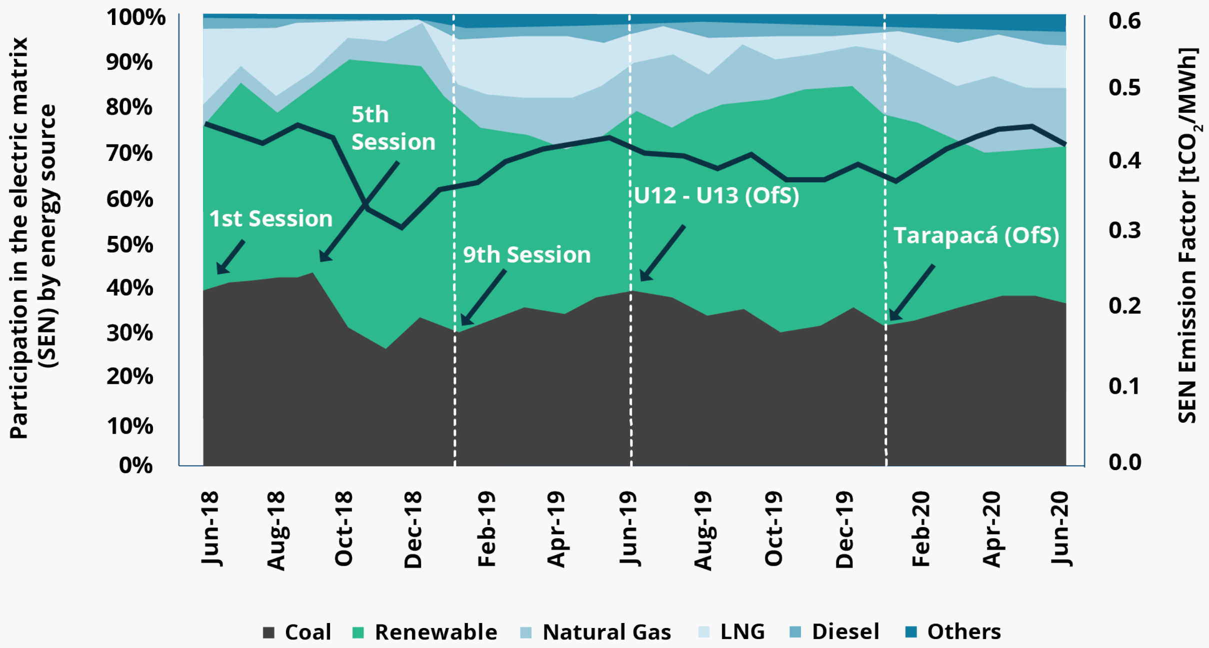


Adapted from CNE (2020a)

5.3 Political developments since the publication of commission findings

The findings of the coal commission triggered a significant shift in discussions surrounding the power system. Since their publication, much greater attention has been devoted to social issues. In pursuing the broader goal of decarbonization, government policy is now informed by the need to consider a range of stakeholders and issues, from local economic conditions to transmission grid expansion. Furthermore, the private sector is actively involved in the process and is now working to identify and study opportunities and new business models compatible with a coal phase-out. The box below contains a summary of the key government climate-related policies and strategies.

Figure A15:
Effects of coal commission on power generation and the grid emission factor



Adapted from CNE (2021)

Chilean climate policies and strategies

Proposed Framework Law on Climate Change
Currently, the draft version of a Proposed Framework Law on Climate Change is being debated by the Senate's environmental committee. This law foresees mechanisms that would accelerate the closure of coal power plants by making their operation less profitable.

Long-Term Climate Strategy
The Long-Term Climate Strategy encompasses considerations and measures related to technical feasibility, social equity, and economic efficiency. As an instrument that defines long-term guidelines, it supports the decision-making process for achieving carbon neutrality. Key elements include: (1) the establishment of a national cap on GHG emissions in 2030, which will decline through 2050; (2) the adoption of sector-based emission caps, with particular ambition in the energy sector over the next decade; and (3) guidelines on climate change adaptation and risk assessments that consider the vulnerabilities of each sector.

Nationally Determined Contribution (NDC)
As the host nation of COP25, Chile has committed itself to the goals of the Paris agreement and the NDC revision process. One objective of the revised Chilean NDC is to fully replace coal power with renewables by 2040.

Just Transition Strategy
A Just Transition Strategy (JTS) is currently being developed at the Ministry of Energy and Environment, and should be published soon. (it was expected to be released in January 2021.) Among other things, the JTS will elaborate measures related to social dialogue, private-sector compensation, and worker protection. In addition to illuminating technical alternatives to coal, GIZ has supported the Chilean government in achieving a just transition and serves on the JTS executive committee (Ministry of Energy, 2020d; 2020e).

Grid flexibility and expansion
The grid regulator CNE is studying the expansion of the transmission grid in order to accommodate and encourage a higher share of renewables. Furthermore, a flexibility strategy, presented in 2020, has been developed to allow renewable plants to enter/exit the system without grid failure or congestion, to incentivize storage, and to maintain the security of supply in a cost-effective way (Ministry of Energy, 2020f). The National Electric Coordinator has estimated that efficient levels of coal-fired plants conversion lie between 30 and 70 per cent of existing capacity. This means that the conversion of around 1,640 MW would be feasible in the short term. Carnot batteries and solar PV technology are regarded as highly compatible (National Electric Coordinator, 2021).

Parliamentary motion to close coal-fired power plants
At the time of this study's publication, Chile's lower house of parliament was still debating a motion for the early closure of coal-fired units. Specifically, the motion calls for units younger than 30 years old to be disconnected by the end of 2025, and for all remaining units to cease operation by the time the law comes into force. However, the National Electric Coordinator estimates that this early phase-out could increase 2026 power system costs by two to three times, while also posing risks to the security of supply (Revistaei, 2020).

Revision of the Supreme Decree 13 / Emission Standards
In February 2020, the Comptroller Office as established by the Constitution, the Office of the Controller General of the Republic (CGR) is a supreme audit institution of the State Administration and autonomous with respect to the Executive Branch and other public bodies. It controls the legality of administrative acts and safeguards the correct use of public funds. Issued ruling No. 2737, instructing the Ministry of the Environment to begin the process of revising the emission standards for thermoelectric plants from 2011. The revision could increase compliance-related operating costs and lead to additional plant closures. However, an official decision on this matter is not currently in the offing.

Revision of the Supreme Decree 42 / Strategic Reserve Status
The amended Supreme Decree 42 allows power plant operators to keep shutdown plants with Strategic Reserve Status (Estado de Reserva Estratégica, ERE) and receive compensatory payments for up to five years (Ministry of Energy, 2020b).

6. Concrete steps to date

Since the first meeting of its coal commission in June 2018, Chile has taken numerous steps to facilitate the phase-out of coal power plants, including agreements with industry to shut down coal-fired units, the ratification of international agreements on carbon neutrality and climate action, and the strengthening of the emissions law. The steps are summarized chronologically below:

- → The Primary Air Quality Law for Sulphur Dioxide (SO2) was adopted in 2018, establishing an hourly limit equivalent to European regulations (La Tercera, 2018; Ministry of Energy, 2020f).
- → In June 2019, the Chilean President, together with heads of state from Germany, France, Spain, the UK, and the Netherlands, established a commitment for Chile to be carbon neutral by 2050, and to have a decarbonized energy system by 2040 (Chilean Government, 2019).
- → In June 2019, companies with coal assets (Enel, Engie, Aes Gener, and Colbún) officially signed an "agreement to phase-out coal-fired power plants".
- → At COP 25 in December of 2019, the Energy Ministry announced the early shut down of 4 units (CTM1, CTM2, Ventanas 1 & 2), to take place before the end of 2024 (CNE, 2019). After COP25, the company Enel announced that the Tarapacá power plant would be shut down in May 2020 (Chilean Government, 2020), and that the closure of the Bocamina I and II plants would be brought forward by 2 and 18 years, respectively.
- → In 2020, the Ministry of the Environment revised Supreme Decree 13, strengthening maximum emission values for particulate matter, nitrous oxides (NOX), and sulfur dioxide (SO2). However, an official decision on this matter is not yet in sight.
- → A Just Transition Strategy is being developed involving stakeholders and civil society from affected regions (Ministry of Energy, 2020d).
- → A draft climate change law is currently under review and it is being discussed by the Senate environmental committee.
- → Technology-neutral tenders for large quantities of electricity are planned for mid-2021 and for the period from 2026 to 2034. The prices determined there will have a direct influence on the costs of decarbonization (CNE, 2020b).
- → In May 2021, Engie announced that it would retire its full fleet of coal-fired plants by 2025. As a result, 50 per cent of Chile's coal-fired units will be retired or converted by 2025.

6.1 Effects of the COVID-19 pandemic

The COVID-19 pandemic has undermined progress on social and environmental issues related to the coal phase-out. On the one hand, COVID has been associated with a generally lower electricity demand, but increased demand for non-regulated costumers in peak hours, increasing the coal power share and emission impacts. Green recovery policies may reverse this trend. On the other hand, as of March 2021, the government had not yet announced specific economic assistance measures to help communities and workers adapt to the coal phase-out.

Section B – Coal Phase-out in Germany

1. Country overview of Germany and its energy system

1.1 Socio-economic structure

With over 83 million inhabitants and a GDP of 4.7 trillion USD, Germany is Europe's most populous country and its largest economy. Unlike many other high-income nations, Germany has maintained a strong industrial base: in 2019, the manufacturing sector accounted for 24 per cent of GDP (falling just one percentage point since 2000). Energy-intensive industries such as steel, chemicals, mechanical engineering, and automobile manufacturing have played a key role in the German economy since the 1800s.

Table B1: Economic indicators for Germany in 2019

Indicator	Data for Germany (2019)
Population size (millions)	83.2
Land area (km^2)	357,582
Population density (number of inhabitants per km^2)	232
Gross Domestic Product (billions of U.S. dollars)	4,659
GDP per capita (USD / per capita)	56,085
Public debt / GDP	70%
Gross domestic savings as % of GDP	10.9%
Most relevant economic sectors (% GDP)	Manufacturing: 24.2% Public services, health, education: 18.8% Commerce, transport, hospitality: 16.2%
Unemployment rate (% of labour force)	3.2%
Gini coefficient (between 0=complete equality and 1=complete inequality)	0.29
Human Development Index (HDI)	0.94
Competitiveness index (score out of 100)	81.8
Energy dependency (net imports / gross available energy, 2018)	63.6%
Primary energy per capita (GJ/p.c.), 2018	165

OECD Statistics (2020), Volkswirtschaftliche Gesamtrechnungen, WEF (2019), Eurostat (2020), The Global Economy (2020)

1.2 Characteristics of the energy system

Germany's energy system has undergone profound change since the reunification of East and West Germany in 1990. One change is that the German economy has become significantly more energy efficient. Primary energy consumption has steadily fallen since 1990, and the economy has grown by more than 50 per cent. Thus, Germany now produces much more value added per unit of energy, as shown in Figure B1.

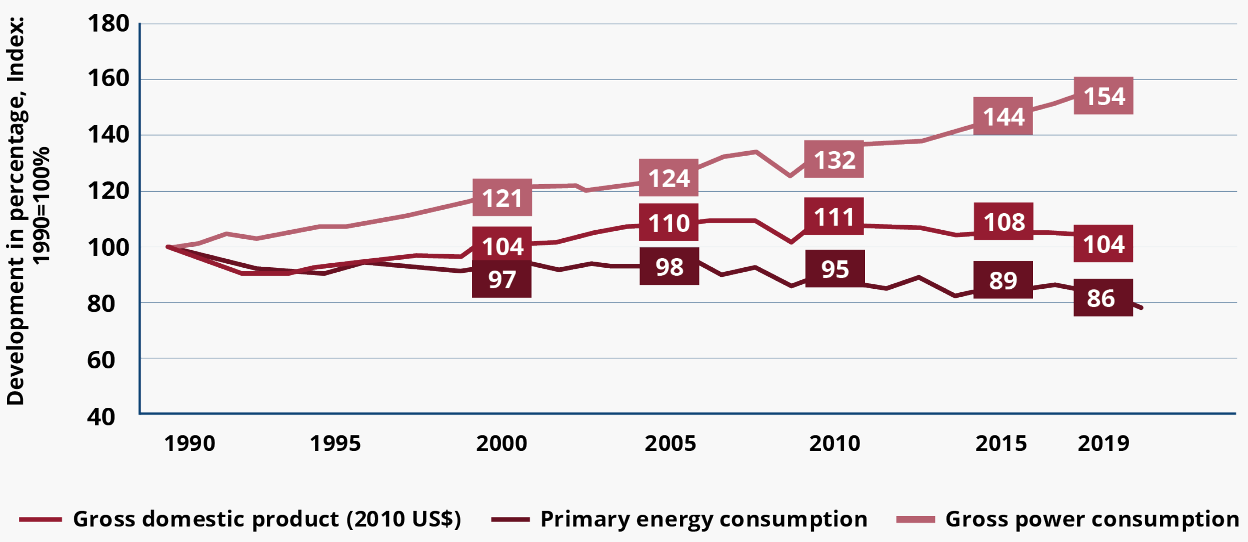
Second, Germany's energy mix has undergone significant change. While coal supplied 37 per cent of all primary energy consumption in 1990, this figure stood at 18 per cent in 2019 (see Figure B2). Similarly, nuclear shrunk from 11 per cent in 1990 to 6 per cent in 2019. Reduced dependency on coal and nuclear has been possible thanks to an expanding share of renewables, which increased from one per cent in 1990 to almost 15 per cent of primary energy consumption in 2019. Natural gas consumption has also increased, rising from a 15 per cent share in 1990 to a 25 per cent share in 2019. By contrast, the share of oil in the energy mix has remained stable at 35 per cent (AG Energiebilanzen, 2020).

The transformation has been most profound in the power sector. While hard coal and lignite supplied 57 per cent of all power generation in Germany in 1990, this figure had fallen to 28 per cent by 2019. Furthermore, because of the 2011 decision to phase out nuclear by 2022, the contribution made by nuclear energy has also declined dramatically– from 28 per cent in 1990 to 12 per cent in 2019.

By contrast, power generation from wind, solar, and biomass has undergone massive expansion, and now covers 40 per cent of German power demand (see Figure B3). Natural gas use in the power sector has also increased in recent years, as relatively low gas prices in combination with a rising carbon price have made natural gas more competitive with coal (AG Energiebilanzen, 2020b).

Total gross electricity consumption in Germany has only increased modestly since reunification, rising by just 5.3 per cent between 1990 and 2019. The share of total final energy consumption used in the form of electricity

Figure B1:
GDP, primary energy consumption, and gross electricity consumption in Germany, 1990–2019
(1990=100%)



Agora Energiewende (2020)

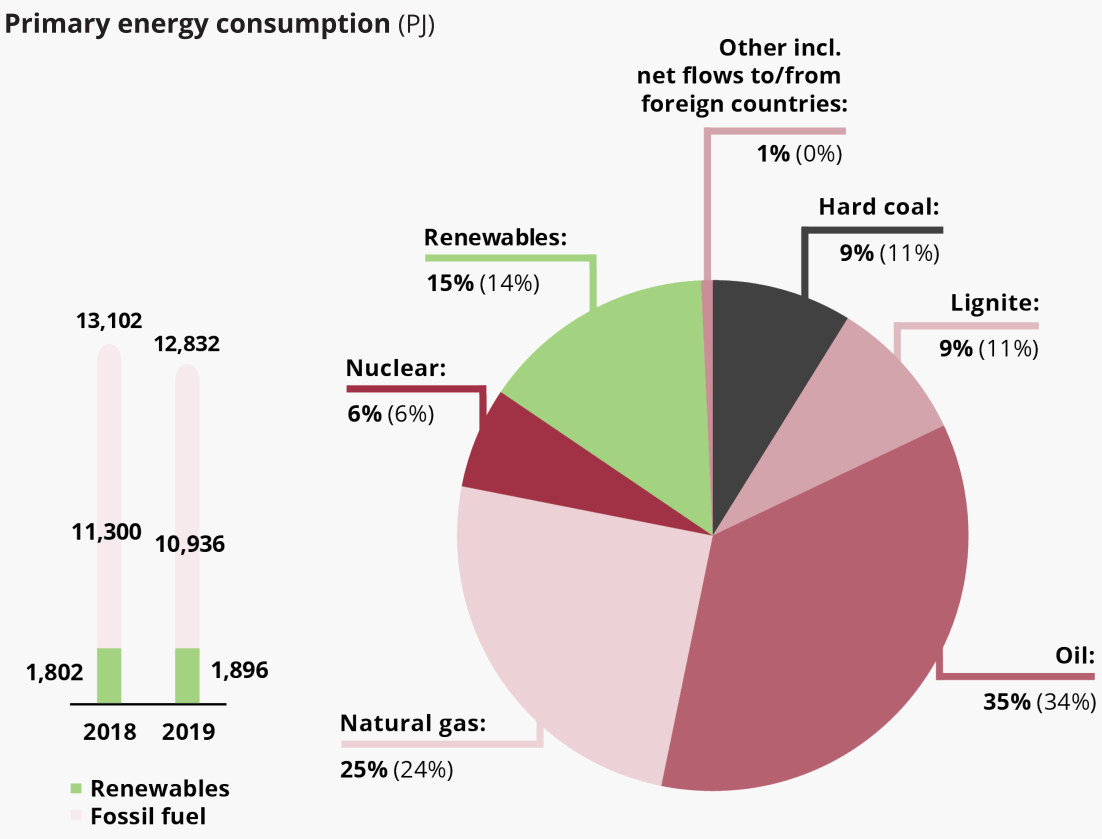
increased from 17.3 per cent in 1990 to 20.6 per cent in 2018.

However, with a total of 580 TWh consumed in 2019, demand is still 3.5 per cent lower than its 2017 peak (AG Energiebilanzen, 2020b). Accordingly, annual gross electricity consumption per capita has increased by less than one per cent over the past three decades – from 6,904 kWh in 1990 to 6,977 kWh in 2019 (AG Energiebilanzen, 2020b; Destatis, 2020; Destatis, 2018).

As a result of energy sector transformation and increased energy efficiency in industry and buildings, Germany reduced its greenhouse gas (GHG) emissions by nearly 36 per cent between 1990 and 2019 (see Figure B4). In absolute terms, the energy sector has contributed to the biggest reduction of 212 $MtCO_{2eq}$ since 1990 by far, equivalent to a 45 per cent reduction.

Looking at progress in other sectors, the buildings sector has achieved an above-average reduction of 42 per cent, while industry and agriculture have reduced their emissions by 34 per cent and 24 per cent, respectively. The transport sector, by contrast, saw increasing GHG emissions into the 2000s, and a subsequent drop to 1990 levels by 2019 (UBA, 2020).

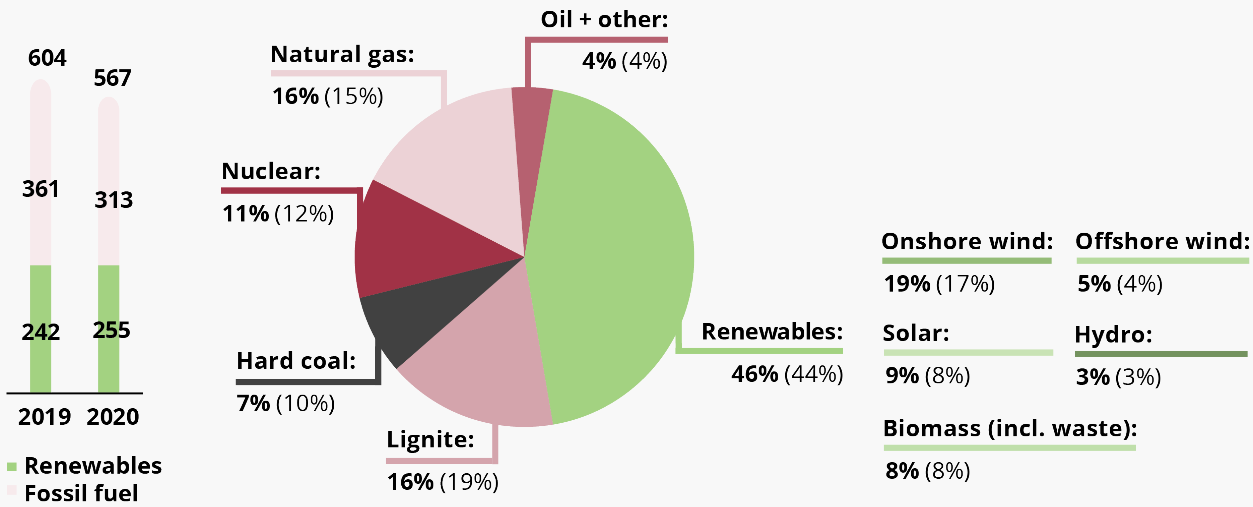
Figure B2:
Primary energy consumption of Germany in 2019 (values for 2018 in brackets)



Agora Energiewende (2020)

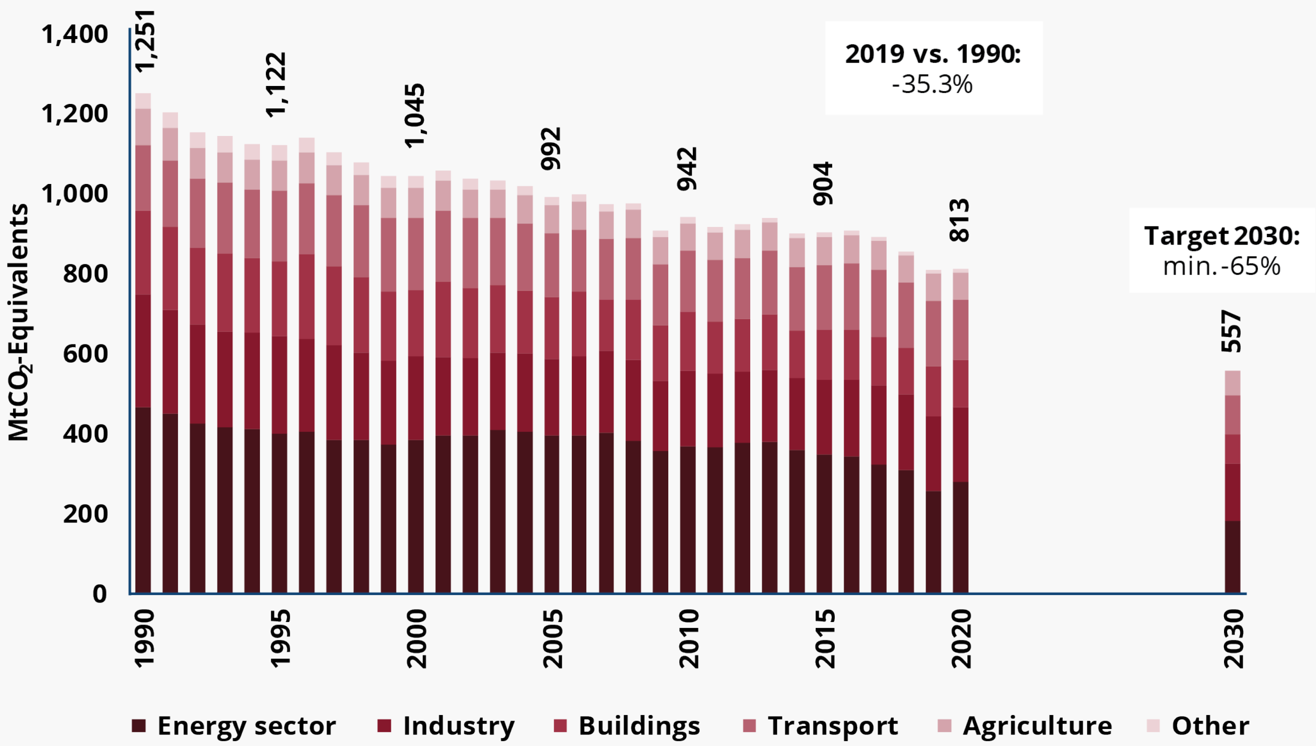
Figure B3:
Electricity mix in Germany in 2020 (values for 2019 in brackets)*

Gross power production (TWh)



Agora Energiewende (2020)

Figure B4:
German greenhouse gas emissions by sector, 1990-2020, and targets for 2030*



* The 2030 emission reduction target is based on the Climate Law 2021 that aims to achieve climate neutrality by 2045 and net removals after 2050. Parliamentary decisions on necessary amendments to the German Climate Law are yet to come.
Agora Energiewende (2020)

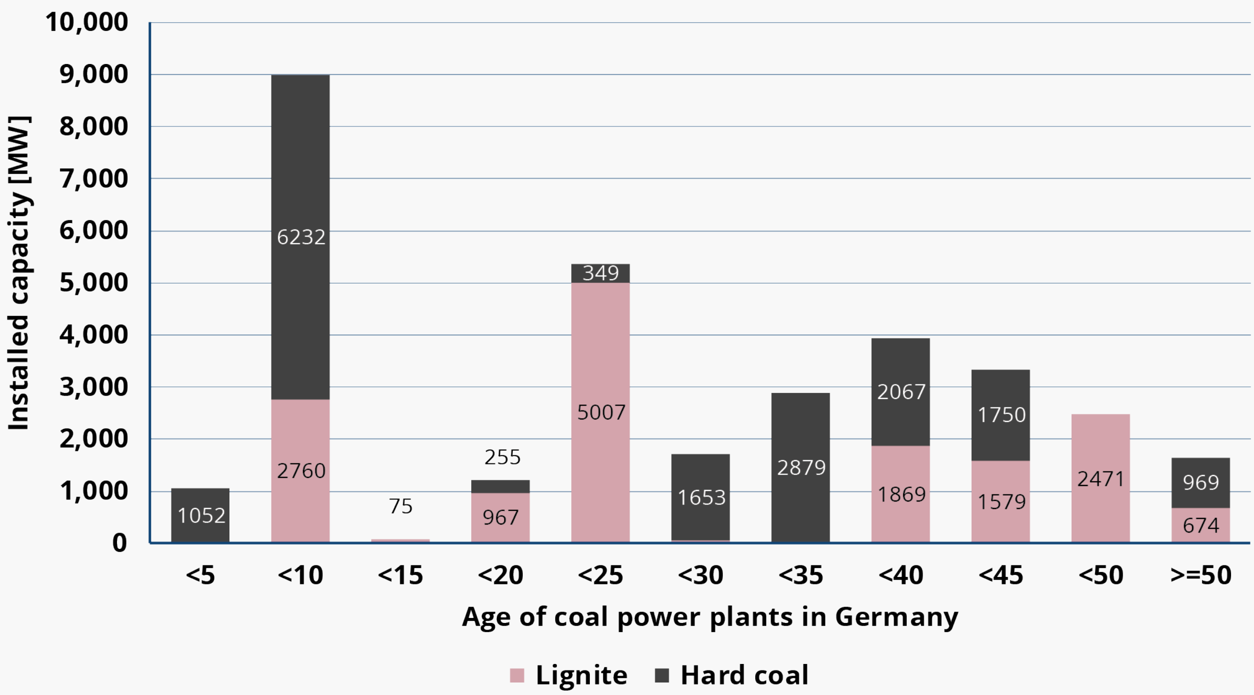
1.3 Power market design

In Germany, the merit-order principle is used to match supply and demand. All participants in the spot market offer electricity at their "marginal cost" of generation – that is, at the cost incurred for one additional kWh of electricity production. To cover consumer demand for electricity within a given hour of the day or night, power is purchased from the generation plants in the order of their bids – from lowest to highest – until all demand has been served. The wholesale electricity price paid to providers who sell their electricity at a given point in time is based on the amount of the last successful bid. The marginal-cost bids of energy providers do not include fixed costs (such as investment costs and fixed costs of plant operation). However, emission certificates are considered a valid marginal cost in the German regulatory system. The environmental effects of power generation are only incorporated in the marginal costs if it has direct economic effects on the operator. This is the case for CO_2 emissions that need to be compensated with an equivalent volume of EU emission trading certificates.

In Germany, renewable energy projects receive financial support based on the rules laid out in the Renewable Energy Sources Act (EEG). Smaller photovoltaic systems and older plants receive a fixed feed-in tariff per kWh for 20 years. Larger plants built after 2018 receive a market premium on top of the spot market price, whose level is determined in regular auctions, so as to reward the lowest bidders. However, all of the electricity generated by EEG-financed renewable energy plants is sold in the spot market – either by professional traders commissioned by the plant owner or by the grid operator (in the case of smaller PV systems). Wind and solar power plants have marginal generation costs of zero, as there are no fuel procurement costs and they do not emit CO_2. In addition, renewable energy enjoys priority status in transmission and distribution grids.

In exceptional cases, it can be economical for the operators of conventional power plants to offer electricity at prices under their marginal cost, because the alternative of shutting down the plant and starting it up again

Figure B5:
Installed capacity of coal-fired power plants by age in Germany



Bundesnetzagentur (2020)

would be even more expensive. This lack of flexibility in the operation of conventional power plants can lead to negative spot-market prices. In 2019, negative prices occurred during 211 individual hours (of 8,760 hours in the year) (Statista, 2020).

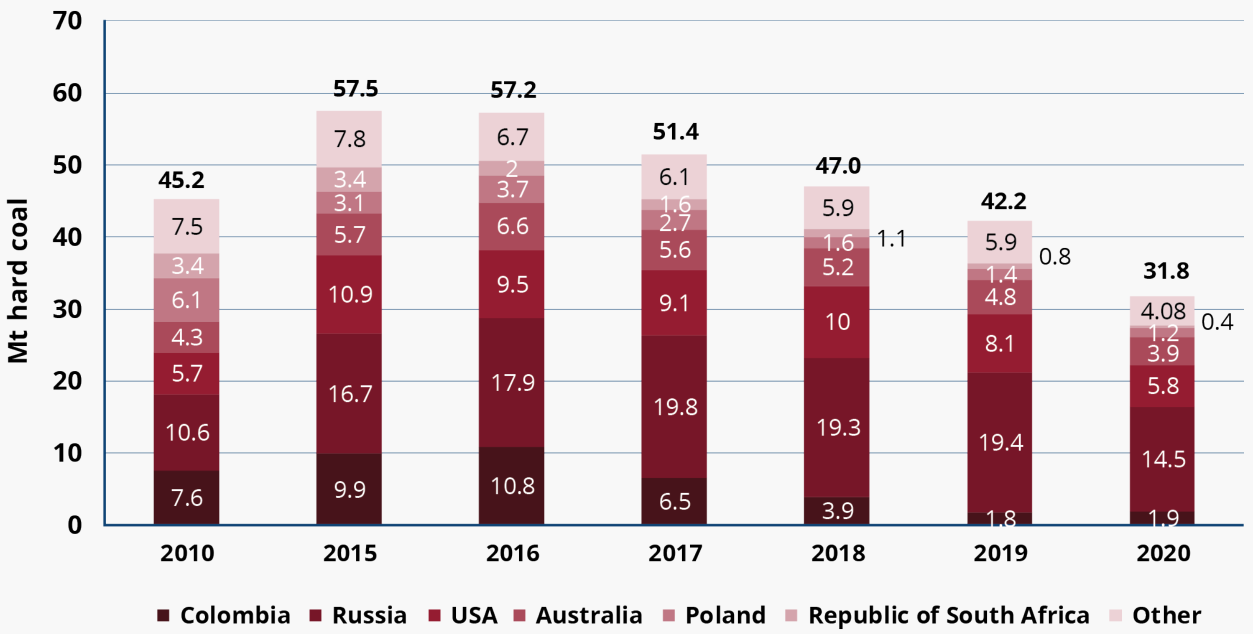
In line with their respective marginal costs, renewable energy plants are typically first in the merit order, followed by nuclear and then by fossil-fuel generation. In recent years, renewable energy has grown to cover the lion's share of demand during many hours of the year. As a result, fossil fuel plants are running less, and the electricity wholesale price has decreased (see Figure B8).

Another important shift that has taken place in the past few years is an increasing reliance on natural gas as a substitute for coal. Higher emissions prices in combination with relatively low gas prices have led modern and efficient gas-fired power plants to overtake older, less efficient hard-coal-fired power plants in the merit order. Lignite plants, by contrast, were initially spared, as they have lower marginal costs than hard-coal plants (due to abundant domestic lignite resources). However, in 2019 and 2020, older lignite-fired plants began to be displaced from the market, in part due to lower power demand during the COVID-19 pandemic (see section 2.3).

1.4 Characteristics of coal mining and use

In March 2020, coal-power capacity in Germany amounted to 20.9 GW of lignite-fired power plants and 22.6 GW of hard-coal-fired plants (Bundesnetzagentur, 2020). Of this amount, some 18.1 GW of lignite capacity and 18.6 GW of hard-coal capacity are currently in operation and contributing power to the market. The remaining plants are held in reserve. The "grid reserve", which consists of hard-coal plants, is designed to cover potential supply bottlenecks during the winter. The reserve includes both redispatch capacities and capacities to maintain voltage or restore power after a black-out in Germany or other countries. The "security reserve", which consists of lignite-fired plants, was introduced in 2016 as a first step in the reduction of total coal capacity. Between 2016 and 2019, lignite-fired power plants with a combined capacity of 2.7 GW were gradually transferred

Figure B6:
Origin of hard-coal imports to Germany



Verein der Kohleimporteure (2020)

to this reserve, and after four years will be retired for good. While plants in the secur security reserve could be activated to counteract a prolonged supply-side bottleneck, this is unlikely, in part due to their limited flexibility. In this way, the security reserve is mainly a tool for compensating operators for closing their plants, as operators receive government compensation (Oie et al., 2019).

Germany's coal power plants vary significantly in terms of their age and efficiency. On average, they are over 30 years old (see Figure B5). Lignite capacity is highly concentrated in the country's three major domestic coal-mining regions: the Rhineland coalfields operated by RWE (10 GW), the Lusatian coalfields operated by LEAG (7 GW), and the Central German coalfields operated by Mibrag and Saale Energie (3 GW). LEAG, Mibrag, and Saale Energie are subsidiaries of the Czech company EPH. Hard coal-fired plants are more dispersed throughout Germany. They are also much more diverse in terms of their size and ownership structures. The large majority of hard-coal plants are cogeneration plants, producing both power and heat. Heating energy is distributed through district heating networks, increasing the plants' overall efficiency.

The last German hard-coal mine closed in 2018 after hard-coal mining had become uncompetitive in the 1970s. All hard coal used in Germany is thus imported. The largest supplier of hard coal to Germany was Russia, followed by the USA and Australia. A small share of hard-coal imports come from Colombia, which also supplies Chile (see Figure B6).

Oie et al. (2019) estimate that the German coal industry directly employed between 22,500 and 26,500 people at the end of 2018 (see Table B2). This includes 18,500 workers in lignite mines and associated power plants. (Available data do not make a clear distinction between mining and power plant employees, due to the integrated nature of lignite operations.) While there are no official data on the number of workers at hard-coal plants in Germany, Oie et al. (2019) estimate this figure at 4,000 to 8,000.

In addition to the effects of direct employment, the coal industry generates jobs indirectly through supply chains and local worker spending. (Oie et al., 2019) have estimated the indirect and induced employment effects of the coal industry at 38,000 to 42,000 additional jobs in 2018. This estimate only includes jobs based in Germany, and does not include employment effects from hard-coal imports. Like most industrial sectors in Germany, workers in the coal industry have strong unions, such as IG Metall and IGBCE, which vigorously represent their interests in the political process.

Table B2: Employees in the coal sector in Germany

	Lignite (open-cast mines and power plants)					Hard coal (power plants)	
Employees	Rhineland coalfields	Lusatian coalfields	Central German coalfields	Rest of Germany	**Total**	Distributed Germany	**Employees Total**
Direct*	-8,900	-7,800	-1,900	0	**-18,500**	-4,000 - 8,000	**-22,500 - 26,500**
Indirect and induced**	-5,300	-4,700	-1,100	-22,100	**-33,300**	-4,800 - 9,600	**-38,100 - 42,900**

Oie, P.-Y. et al. (2019)
*Lignite: employees in lignite mines and the lignite-fired power plants for public power supply in 2017 (Coal Industry Statistics 2018); data excludes the Helmstedt coalfields and employees of the Lausitzer und Mitteldeutsche Bergbau-Verwaltungsgesellschaft mbH (LMBV) for open-cast mine recultivation (Lusatian coalfields: 410 employees, Central German coalfields: 210 employees) (Öko-Institut, 2018a); hard coal: 5,000 to 9,000 employees in the hard-coal-fired power plant in 2016 minus 800 to 1,000 employees due to job cuts at Steag (SRU, 2017).
** Lignite: factor 1.6 in the coalfields and 2.8 for the rest of Germany (RWI, 2017); Hard coal: factor 1.2 based on an average factor of 0.6 for hard-coal mining (GWS, DUR, and DIW Berlin, 2018) and in line with the data from Öko-Institut (2017b), that lignite-fired power plants generate roughly twice as much indirect employment as lignite mining.

2. Driving forces for energy transition and coal phase-out

2.1 Overview of the energy transition

After the Fukushima accident of 2011, the German government decided to phase out all nuclear energy by 2022 and to significantly increase renewable energy use. While this decision – known as the Energiewende ("energy transition') – may have appeared abrupt at the time, it was actually the outcome of a long and gradual process. The first government timetable for phasing out nuclear power had actually been adopted 11 years prior, in 2000, following a protracted public debate on nuclear energy that began in the 1970s. Ironically, in 2010, Chancellor Merkel overturned the phase-out decision of 2000, only to perform a volte face seven months later, following Fukushima.

In the 1990s, rising concern about climate change became a second driving force behind the German transition to clean energy. Concern about the state of the climate prompted the government to adopt its first emission reduction target, to strengthen energy efficiency, and to explore alternative sources of energy. The expansion of renewable capacity began in earnest with the adoption of the Renewable Energy Sources Act (EEG) in 2000, which provided guaranteed remuneration of renewable energy producers in the form of a feed-in tariff. In addition to this policy measure, the German government worked to advance climate protection efforts at the EU and international levels.

Due to the focus on phasing out nuclear and the early successes in renewable energy expansion, the call for ending coal-fired power generation only started to take centre stage in the German debate after 2011. Yet when it became clear that emissions from coal power plants had continued to increase despite the rapid expansion of renewable energy capacity, pressure from environmental NGOs to tackle the issue increased. The government delayed decisions on national instruments to organize the coal phase-out several times, but finally decided to convene a stakeholder commission in 2018. In early 2019, the Fridays4Future movement emerged, inspiring 1.4 million people to participate in Germany's largest climate demonstration to date. The movement – and the experience of two extremely hot and dry summers – increased public pressure to strengthen climate policy in general and to phase out coal in particular.

2.2 First driving force: Germany's climate and energy targets

Germany has a comprehensive set of climate and energy targets that have been revised several times since their inception. Some targets represent national goals, while others are binding or non-binding contributions to EU-wide targets. The EU, in turn, has made commitments at the international level, as set forth in its Nationally Determined Contributions (NDC) under the Paris Agreement.

Germany's goals include:

- A 65 per cent GHG emissions reduction by 2030 relative to 1990 levels and achieving greenhouse gas neutrality by 2045. The 2030 target is broken down into sector targets (energy, transport, buildings, agriculture, waste). The energy sector must achieve a reduction of 77 per cent relative to 1990 levels.
- Helping to reduce EU-wide emissions in the Emissions Trading Scheme (ETS) by 43 per cent in 2030 relative to 2005 levels.
- A reduction of GHG emissions in the sectors outside ETS by 38 per cent relative to 2005 levels (a binding obligation under the EU Effort Sharing Regulation).
- A reduction of primary energy consumption by 30 per cent in 2030 relative to 2008 levels (a non-binding contribution to the EU-wide target on energy efficiency improvement).
- An increase of the renewable energy share in total gross energy consumption to 30 per cent by 2030 (a non-binding contribution to the EU-wide target for expanding renewables).
- An increase in the share of renewable energy in gross final electricity consumption to 65 per cent by 2030 (a national goal laid down by the Climate Action Law of 2019).
- The closure of all remaining nuclear power plants by 2022 (a national target enshrined in the

13th Amendment to the Atomic Energy Act).

Prior to 2019, the German government also had a climate policy goal for 2020 – namely, to achieve a 40 per cent reduction in GHG emissions relative to 1990 levels. After years of slow progress, the target appeared unattainable, and was thus abandoned. However, recent calculations indicate that Germany has fulfilled its 2020 target due to higher emission prices, lower natural gas prices, mild winter weather, and the effects of the pandemic (Hein, 2020).

2.3 Second driving force: Key policy instruments in the energy sector

Decarbonization in Germany's power sector is driven primarily by two instruments: the European Emissions Trading Scheme (EU ETS) and the support scheme for renewable energy expansion (EEG).

Introduced in 2005, the EU ETS establishes a progressively declining cap on the amount of CO_2 that power plants can emit[10]. Power plants and industrial facilities governed by the ETS must submit one emission allowance (or certificate) for each tonne of CO_2 they emit. Emission allowances can be freely traded, thus allowing the formation of a price per tonne of carbon emissions. In this way, electricity generation becomes more expensive if a plant is inefficient or relies on CO_2-intensive fuel. This provides an incentive to switch to more efficient technologies or lower-carbon fuels. The ETS thus strives to integrate the external costs of CO_2 emissions and climate change into the formation of electricity prices.

The ETS suffered for many years from a substantial certificate glut due to initial over-endowment in combination with slower than expected economic activity after 2008. The certificate price hovered below 10 euros per tCO_2 between 2012 and 2018, at times even dipping below 5.

To address these low price levels, the ETS system was reformed in April 2018. One key change was to establish a market stability reserve into which surplus certificates are deposited and ultimately deleted. The spot price for ETS certificates subsequently climbed to over 20 euros per tCO_2 (see Figure B7). More recent movements to over 40 euros per tCO_2 might reflect anticipation of a stronger GHG target for 2030, as foreseen by the European Green Deal (European Commission, 2019). A more ambitious target would mean a lower EU ETS cap and thus induce a higher certificate price.

The second key instrument for driving transformation in the German power sector is the Renewable Energy Sources Act (EEG). The EEG grants renewable energy priority access to the power grid as well as priority status for transmission and distribution. Under the law, renewable energy operators are provided feed-in premiums on top of the market price or, alternatively, fixed feed-in tariffs for each kWh they produce, in each case for a period of 20 years. Prior to 2017, the law did define the exact amount of the feed-in tariff. Feed-in tariffs varied by technology and depended on the plants' location and size. In this way, the EEG has helped to encourage a range of technologies, and not just the most cost-efficient ones. Tariff levels automatically decrease over time in order to reflect cost and efficiency improvements as technologies mature.

Renewable plant operators can sell their electricity directly to the spot market. Referred to as "direct marketing", this mechanism for direct sale incentivizes operators to improve their output forecasts and to react flexibly to spot prices. Power fed into the grid by small providers is subsequently sold by Germany's four Transmission System Operators on the spot market. The grid operators recover the difference between the wholesale market price and the feed-in tariff (or the premium) through a levy on electricity prices. In 2020, this EEG levy was 6.76 ct/kWh. Some energy-intensive companies are exempt from paying this levy in order to safeguard their international competitiveness.

As part of the EEG amendment enacted in 2016, fixed feed-in tariffs were replaced with a competitive bidding system. After pilot tender procedures for free-field solar plants in 2015/16, an auction system was launched for all renewable energy technologies in 2017. As a sole exception, small solar plants with an installed capacity

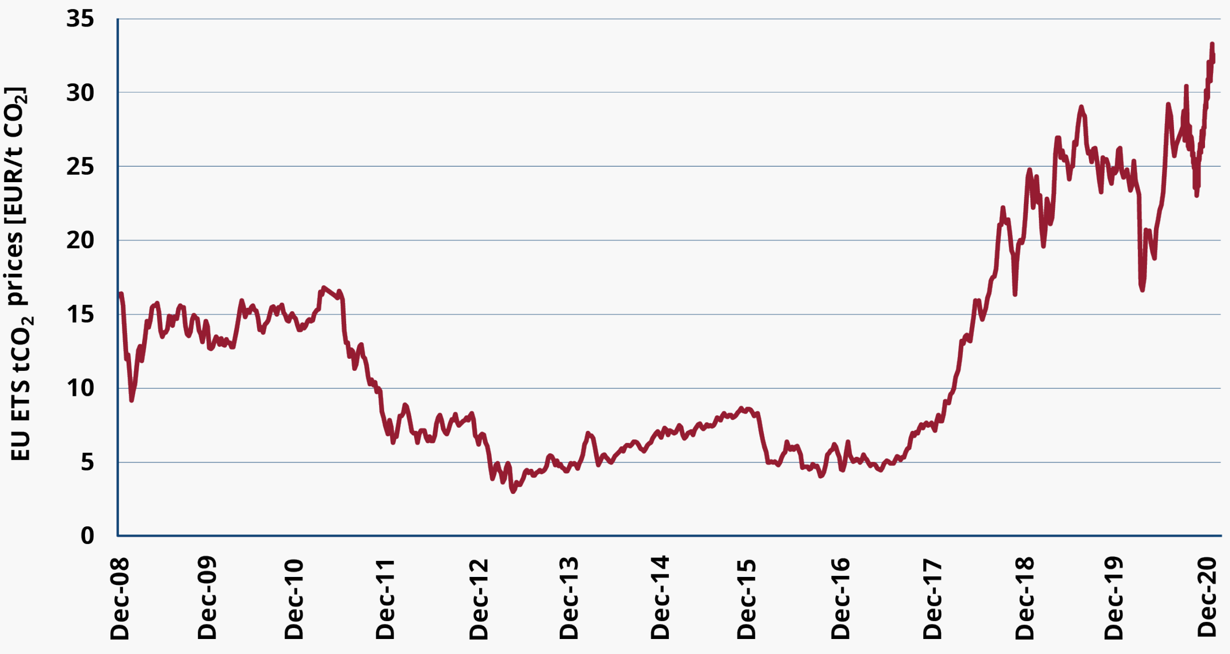
10 This section on the EU ETS draws on Oie et al. (2019)

of less than 750 kW continue to receive fixed feed-in tariffs. Under the EEG 2017, renewable energy operators still receive market premiums guaranteed for 20 years. However, the level of support is no longer determined by policymakers, but by comparing offers from market participants for a given quantity of renewable energy capacity. Auctions are technology-specific, with the auction format varying by renewable energy source. The auction rules for offshore and onshore wind, for example, aim to improve the coordination of capacity additions and grid expansion.

The EEG has been extremely successful in spurring investment in onshore and offshore wind power, PV, and biogas; in the first half of 2020, renewables nearly accounted for 50 per cent of final electricity consumption (Hein, 2020). The feed-in tariff system, which helps to minimize investment risk, has enabled households, farmers, cooperatives, and small companies to invest in renewable energy, often at a lower rate of return than that expected by utility companies.

Together with early investments in other European countries like Spain and Italy, the large-scale investment triggered by the German EEG has helped to drive down equipment costs, prompting a global surge in renewable energy investment.

Figure B7:
Spot price for EU ETS allowances in EUR/tCO_2, 2008-2020



Sandbag (2020)

2.4 Third driving force: Effect of the electricity market on coal power plants

Coal-based power generation in Germany was hard hit in 2019 by a combination of high carbon prices, record renewable energy generation, and low natural gas prices. While hard-coal generation had previously been on the decline, 2019 was a watershed, as year-over-year generation fell by 31 per cent. The change in lignite was even more stunning after supplying roughly the same amount of power for 25 years, lignite-based power generation registered a year-over-year decline of 22 per cent in 2019.

The COVID-19 pandemic has only exacerbated these trends. In the first half of 2020, generation from hard coal was down 46 per cent compared with the first half of 2019; the corresponding decline for lignite was 37 per cent. Aside from the ongoing effects of higher certificate prices and low natural gas prices, lockdown measures are also part of the story, resulting in a -3.5 per cent drop in power demand. Yet the decline of coal is also being driven by the low flexibility of coal-fired plants. Gas-fired plants incur lower marginal costs when ramping production up and down, thus making them better suited to complement variable feed-in from renewables (Agora Energiewende, 2020).

In the absence of a fundamental change in natural gas and carbon prices, the gradual, market-driven decline in coal-fired generation is likely to continue. In addition to impacting dispatch decisions, the market environment is also reducing the overall profitability of coal plants, as they must cover fixed costs with reduced revenues (Carbon Tracker, 2020). While several unprofitable hard-coal plants have been shut down in recent years, this is not the case for lignite plants. There are several reasons for this. First of all, the slump in lignite output is relatively recent, and is in part a result of the exceptional circumstances of the COVID-19 pandemic.

Furthermore, the economic decision to close a lignite plant is more complex than for a hard-coal plant due to their close integration with open-pit mining. Lignite mines have high fixed costs that cannot be offset by simply closing the power plant or cutting back power production.

Finally, the accompanying political process that began in early 2018 included the prospect of compensation for operators who remove plants from the market - thereby creating an incentive to stay in operation despite financial losses, so as to remain eligible for potential government compensation for closure. The compensation scheme for lignite plants was finally agreed to in 2020, but is still under review by the European Commission. Thus, the incentive to stay in the market until the decision is settled remains in place.

3. The coal commission

3.1 Establishment of the coal commission

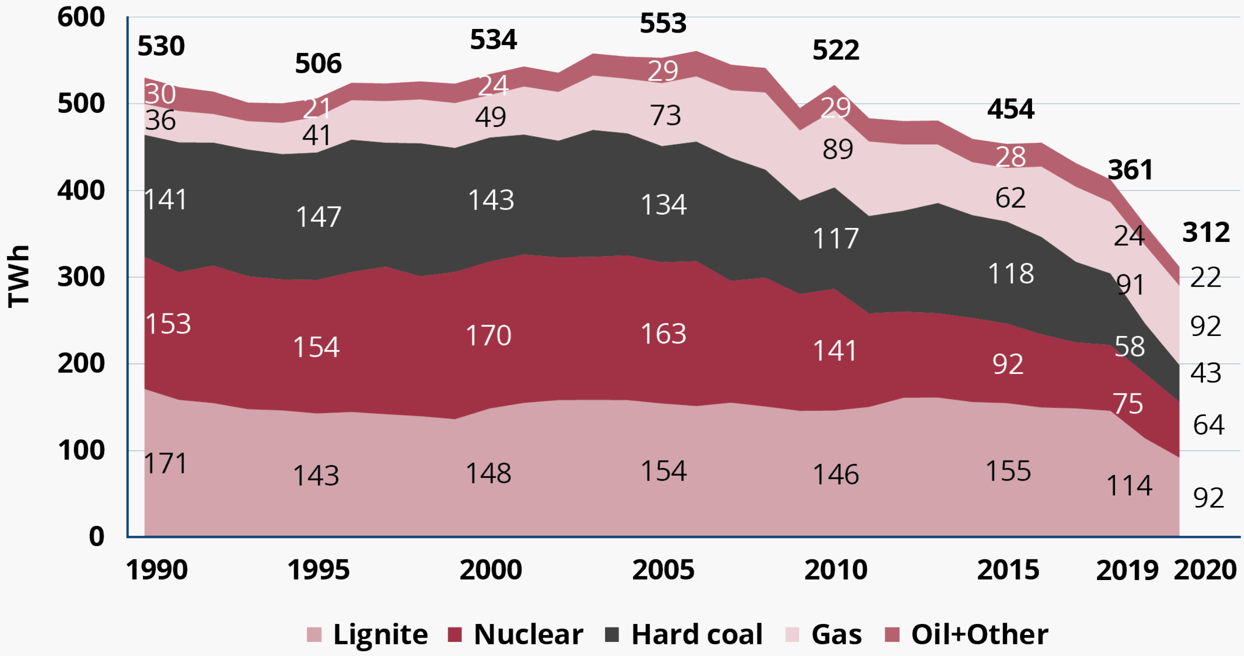
Into the 2010s, it became abundantly clear that Germany needed to address its reliance on coal power. Between 2009 and 2013, power sector emissions increased despite concurrent growth in renewables. While emissions reductions were achieved from 2014 onward, 2018 power sector emissions were only slightly below their 2009 levels. One main reason was the continued prominent role of coal in the power mix. Indeed, between 2010 and 2017, power generation from lignite remained almost unchanged (at about 150 TWh), as did CO2 emissions from lignite combustion (156 Mt in 2010 compared to 155 Mt in 2017). Different factors explain the continued reliance on coal. First was the absence of a meaningful CO2 price. The EU ETS price per tonne remained below 10 euros from late 2011 until 2018, and was thus far too low to stimulate a fuel switch from coal to gas or from lignite to hard coal. The second was the diverging price trends for natural gas and hard coal, with hard-coal prices falling by half between 2011 and 2016, while natural gas prices remained elevated. The third was the boom in electricity exports from Germany, which have reached a level of more than 50 TWh annually – equivalent to about 8 per cent of the country's gross power generation. As a result, newly added renewables capacity did not supplant coal, particularly during the 2010–2015 period. Instead, exports increased and the share of natural gas declined[11].

Continued reliance on coal power was a key reason why Germany was expected to miss its 2020 emissions target – reducing emissions 40 per cent from 1990 levels)[12]. One aspect of the government response was to update Germany's targets for 2030. The Climate Law 2021, being discussed in parliament, defines targets for each sector of the economy up to 2030. To achieve the overall objective of a 65 per cent reduction below 1990 levels by 2030, each sector is expected to make a specific contribution, ranging from 38 per cent for agriculture to 68 per cent for buildings. The energy sector is supposed to reduce its emissions by 77 per cent by 2030, shrinking its absolute emissions to 108 $MtCO_2$ (versus 330 $MtCO_2$ in 2017). While the Climate Law 2021 does not specify the share of these emissions attributable to coal, internal government estimates suggest the need to reduce coal emissions to 84–92 Mt by 2030 (versus 235 Mt in 2017).

In the run up to the 2017 general elections, it had become evident that the issue of coal use required an urgent political answer if Germany was to retain any hope of meeting future emission targets. As a result, discussions surrounding a coal phase-out featured prominently in the coalition negotiations between conservatives (CDU/CSU), libertarians (FDP), and the Greens. However, these parties failed to form a government – in part because of their failure to achieve a consensus on coal. While the new "grand coalition" between the conservatives (CDU/CSU) and Social Democrats (SPD) also came to an impasse on coal, the pressing nature of the issue had become clear in the coalition negotiations. As a result, the coalition agreement that the two parties adopted in February of 2018 pledged to form an independent stakeholder commission. This commission was tasked with examining how coal use could be reduced in line with the government's climate objectives. Three months later, in May 2018, the Federal government issued the formal declaration that defined the mandate of the Commission and named its members and presidents.

11 Even the concurrent phase-out of nuclear power did not change this. The increase in power generation from renewables was almost twice as large as the reduction in nuclear power. Between 2010 and 2015, nuclear power production fell by 46 TWh (from 133 to 87 TWh), but at the same time electricity production from renewable sources increased by 80 TWh (from 102 to 182 TWh). For more, see https://www.energy-charts.de/energy_pie.htm
12 In 2020, it became clear that Germany will probably reach this target thanks to the re-emergence of the carbon price and, more decisively, the rapid contraction in electricity demand caused by the Covid-19 pandemic (Hein et al., 2020).

Figure B8:
Gross power production from conventional energy sources in Germany, 1990-2020



Sandbag (2020)

3.2 Stakeholder composition

The “coal commission” – or, more formally, the “Commission on Growth, Structural Change and Employment” – was formally set up in June 2018 as an independent advisory body charged with representing a broad range of stakeholders. The 28 full members of the commission were selected by government decree, and included:

- Five representatives from business and industry;
- Four representatives of business associations for the energy sector;
- Three representatives of trade unions;
- One representative of the state employment agencies;
- Seven representatives of the coal-mining regions – both elected local officials and representatives of local civil society organisations;
- Five representatives from academia and science;
- Three representatives from environmental NGOs.

In addition, the commission included three members of parliament who had the right to speak, but not the right to vote.

The commission itself was independent of the federal government and consisted of independent members. At the same time, the Commission was embedded in a political process, in which several government institutions played a role:

- The operational work of the commission was supported by a permanent secretariat, which was jointly staffed by the Federal Ministries of Economy and of the Environment.
- The meetings of the Commission were attended by representatives of eight federal ministries and the chancellery, and of the four federal states where lignite mining is located.
- Parallel to the deliberations of the commission, a group of state secretaries from the eight federal ministries provided support to the process; in addition, several ministers and state secretaries appeared at commission sessions as invited guests.
- The four presidents of the commission held several high-level meetings at the chancellery, with the relevant ministers, the prime ministers of the federal states, and Chancellor Merkel involved.

In this way, while the commission was formally independent, a political process accompanied its deliberations to ensure that its findings would be grounded in political reality, and would thus have a good chance of being implemented.

3.3 Function and mandate

The commission was entrusted with a broad mandate. In addition to developing a plan for phasing out coal in line with the government's climate objectives for the coming decades, it was tasked with safeguarding economic development and jobs in coal-mining regions, without endangering the reliability or affordability of the power system.

Specifically, the commission's task was to develop an action plan that would simultaneously fulfil several objectives:

- to create tangible opportunities for the future development of coal-mining regions, in terms of jobs and economic growth;
- to devise policy instruments capable of delivering the coal phase-out while also ensuring economic development and structural change, without social dislocation;
- to identify solutions for funding public investment and to incentivize private investment to boost the development of the affected regions and sectors;
- to propose solutions for reliably achieving the 2030 emissions target for the energy sector, and for subsequently reducing and ending the use of coal power in Germany.

This broad mandate is evident in the structure of the coal commission's final report: the first half addresses the transformation of the energy sector, while the second half discusses support for impacted regions and sectors.

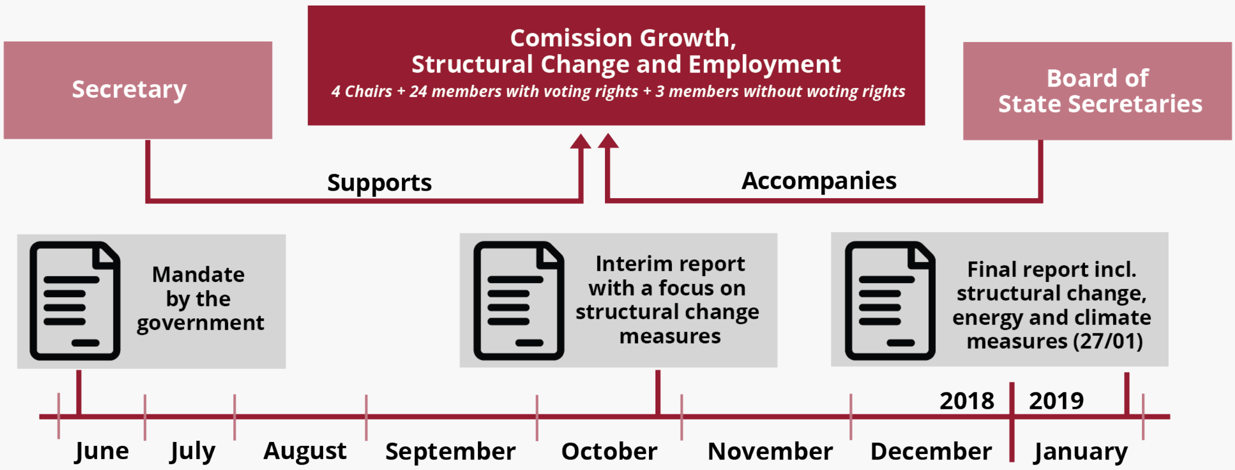
3.4 Timeline and operational aspects

In an intensive deliberative process, the commission held 13 plenary meetings between June 2018 and January 2019. The initial meetings mostly consisted of expert hearings – in all, 65 experts were invited to present their insights on various aspects of the coal phase-out. Three of the plenary sessions were held as field trips to coal-mining regions. These sessions placed a particular emphasis on soliciting views from local stakeholders and their opinions on the development opportunities of the regions.

During the second half of the commission's deliberations, two separate working groups for drafting the report were established. The first focused on elaborating specific steps for exiting coal, while the second focused on issues related to regional development, structural change, and employment. These working groups were then tasked with preparing the draft recommendations, as documented in the 125-page final report of the commission.

After intense negotiations, the commission adopted its final report during its last session on 25 January 2019, with an overwhelming majority of 27 votes in favour and only one against.

Figure B9:
Timeline and structure of the coal commission in Germany



Agora Energiewende (2019)

3.5 Political role and legitimation of results

The commission's report was positively received by the federal government and the broader public. While the recommendations made by the commission were not legally binding, they had a strong impact on policy formation due to the official character of the commission and its representative composition. Policymakers were acutely aware that close adherence to the commission's recommendations would make it difficult for key stakeholders to walk away from the compromise or campaign against it. In this way, the commission's recommendations defined a well-balanced path between competing interests and pacified what might have become a major societal conflict.

With its recommendations, the commission played the ball back into the Federal Government's court. The report included concrete policy recommendations for achieving the phase-out, and stressed that the necessary policy enactments would need to take place by the end of 2019 if the timeline presented in the report was to be realised.

4. Findings and recommendations of the coal commission

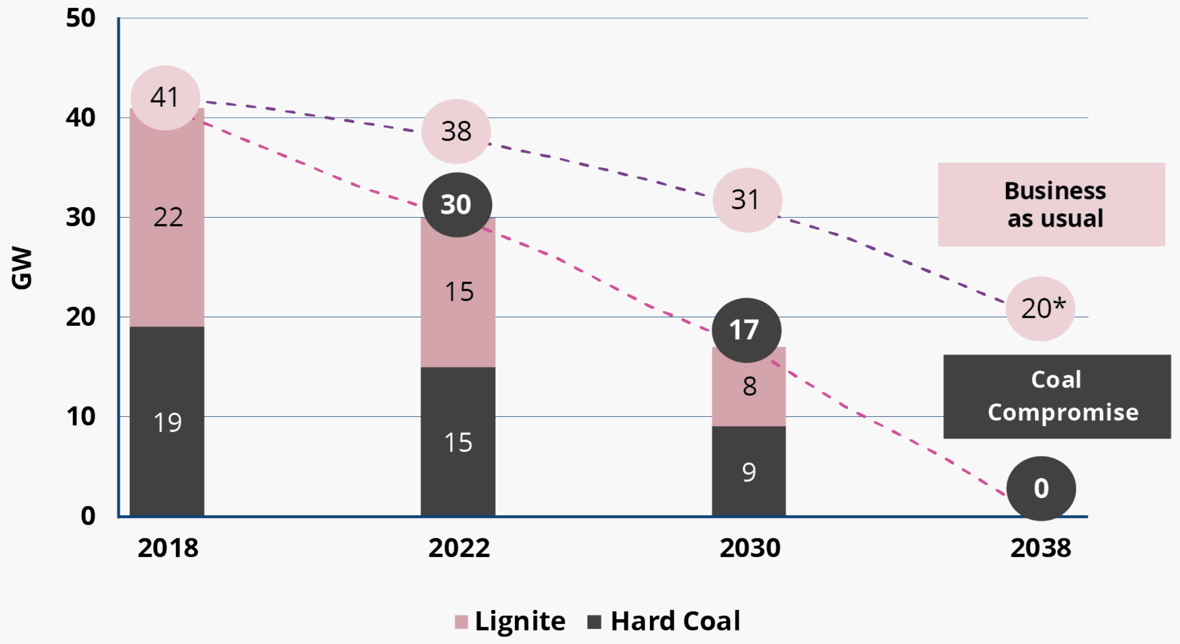
4.1 Coal phase-out and climate targets

The Commission recommended that no new coal-fired power plants be connected to the grid and that no new lignite mines be developed. Furthermore, the commission recommended reducing existing coal-fired capacity in three phases, as shown in Figure B11. In the first phase (until the end 2022), significant plant shutdowns would take place. By the end of this phase, coal capacity would be reduced to a maximum of 30 GW (15 GW of lignite and 15 GW of hard coal), according to the commission's recommendations. In the second phase (lasting up to 2030), capacity would be steadily reduced to 17 GW (consisting of 9 GW of lignite and 8 GW of hard coal). In the third and final phase, all remaining plants would be shut down by the end of 2038. The commission also recommended that a review be conducted in 2032 to determine whether the phase-out date could be brought forward to 2035. The commission's recommendations did not set interim deadlines or milestones between 2022, 2030, and the final phase-out in 2038. This was ultimately a concession to certain stakeholders.

However, the commission did stipulate that capacities should be steadily reduced during each phase, and that a significant step, corresponding to an emission reduction of 10 $MtCO_2$, should be taken in 2025. In this way, the commission sought to ensure that the phase-out would occur gradually, rather than in three sudden waves following interim periods of inaction.

In addition to a timeline for phase-out, the commission also recommended a mechanism for closure: in the case of lignite plants, it was recommended that the government negotiate individual agreements with the operators of each plant, including compensation payments that decrease over time. In the case of hard-coal plants, the commission recommended the use of a competitive bidding mechanism whereby operators would offer to retire plants in return for compensation. Each year, a predetermined amount of capacity would be retired in the order of the most competitive bids.

Figure B11:
Visualisation of the Coal Exit trajectory recommended by the German coal commission



Agora Energiewende (2019)

The commission's recommendations were ultimately geared to the target set in the 2016 Climate Action Plan, which foresees residual energy sector emissions in 2030 of 175–183 $MtCO_2$ (61–62 per cent below 1990 levels). However, the commission did not propose a specific reduction trajectory. Rather, it merely specified targets for the remaining coal-fired capacity.

4.2 Support for mining regions

Beyond the coal phase-out, a core element of the recommendations concerned structural policy measures to support the transformation of coal-mining regions. These measures aimed to replace economic value creation and jobs lost in coal mining (and associated sectors) with new economic opportunities, particularly in industry.

To this end, the commission's final report also elaborated potential development scenarios for each coal-mining region based on information and perspectives gathered from regional stakeholders. Under the scenarios, each region would continue to be defined as energy regions – yet would transition to modern energy technologies, including renewables, energy storage, and green hydrogen. In this regard, the final report elaborated numerous concrete steps (based on opportunities identified by local stakeholders) that would facilitate regional transformation, including the development of new research, communications, transport, and energy infrastructure, but also measures to strengthen civil society on the ground.

To ensure that these measures would achieve the desired effects in time, the commission additionally recommended that planning processes in the regions be accelerated by relaxing certain regulatory constraints. Finally, the commission recommended that federal government agencies with a total of 5,000 employees be located in the coal regions.

To fund these measures, the commission recommended the allocation of up to 40 billion euros over a twenty-year timeframe. It also made proposals for how to administer and disburse these funds. The commission envisioned that 14 of the 40 billion euros would be administered by the regions directly, through local agencies. The remaining 26 billion euros would be distributed through federal programmes in order, say, to support investment or establish research organisations.
A further recommendation made by the commission was to provide insurance coverage for the potential bankruptcy of open-cast mine operators, in order to cover expenses incurred by local governments for the environmental restoration of mining sites.

4.3 Effects on the power system

The commission clearly understood the coal phase-out as one piece of a much larger roadmap for modernizing the power sector. To this end, the Commission stressed the need to closely link the coal phase-out to the expansion of renewable energy. To achieve the goal of a 65 per cent renewables share in gross electricity consumption by 2030, the commission recommended a corresponding amendment to the Renewable Energy Sources Act, in addition to continued support for combined heat and power (CHP) generation.

The commission also addressed the need to make electricity and energy systems more flexible as part of the broader transition to renewables. To this end, the commission highlighted the need to expand and modernize power grids, improve market mechanisms, and optimize existing transmission capacity, in part through support for energy storage technologies.

A crucial criterion for the commission was ensuring that security of supply in the power sector did not suffer. The Federal Network Agency (Germany's grid regulator) will have a strong oversight role. Section 13b of the Energy Industry Act makes all power plant closures subject to approval by the Federal Network Agency. Accordingly, it may veto any closures that jeopardize system stability.

The commission also recommended additional measures to improve the monitoring of security of supply, including closer collaboration at the European level. In the event of insufficient market investment in new plants over the medium term, the commission highlighted the establishment of capacity market as a potential solution. Furthermore, to ensure a sufficient supply of heat energy, the commission recommended continuing support mechanisms for CHP plants until 2030, including support for the replacement of coal-fired power plants with CHP facilities.

The possible effects of the coal phase-out on electricity prices were an issue of heated debate. Because economic modelling gave no clear indication as to whether the phase-out would lead to higher prices, the commission recommended that the federal government compensate household and commercial customers for increases in electricity prices if and when they occurred. Furthermore, the commission recommended that an assessment be conducted in 2023 to ascertain whether the coal phase-out had indeed led to electricity price increases, including the magnitude of the increase. However, the commission did not foresee a specific form of compensation. Rather, it envisioned counterbalancing in the broader reform of energy taxes and levies.

Finally, the commission also considered the European effects of the German coal phase-out. To ensure that the retirement of coal-fired generation would not induce emission increases elsewhere, the commission recommended cancelling CO_2 emission allowances in the EU Emissions Trading System in direct proportion to coal-emission savings[13].

4.4 Assistance for affected groups

To mitigate or avert undue hardships for the groups most affected by the phase-out, the commission proposed a package of support and compensation measures. In concrete terms, the commission recommended extensive labour market measures to benefit those currently employed in the coal industry, including protections against dismissal, provisions for retraining, and measures for shifting workers to new jobs. In the case of employees aged 58 and above, the commission recommended allocating funding for early retirement without reduced pension benefits.

Furthermore, the commission called on German state governments to engage in dialogue with the residents of strip-mining regions potentially facing resettlement, and to adjust strip-mine development plans as soon as possible in accordance with the commission's recommendations. These consultations are to be carried out with the goal of avoiding environmental devastation and resettlement that is no longer necessary, while giving certainty to those still affected by possible resetlement.

By recommending dialogue, the Commission recognized that while new and unnecessary mine development must be avoided, there can also be instances where resettlement is already underway, or where local communities prefer to have certainty and receive compensation rather than experience continued uncertainty.

4.5 Monitoring and adjustment

The members of the commission were fully aware that the successful implementation of the proposed phase-out schedule would hinge on a number of factors, from the expansion of renewables and the safeguarding of security of supply to the creation of new jobs and economic value chains in the affected regions. To ensure successful implementation in all areas, the commission recommended that policy implementation be closely monitored and regularly reviewed. Specifically, it called for progress reports to be submitted to the federal cabinet and German parliament in 2023, 2026, and 2029. Furthermore, an independent panel of experts is to be entrusted with evaluating implementation. If implementation falls behind schedule, or if the underlying conditions change in a significant way, the federal government should revisit the schedule and modify it as necessary.

13 All coal-fired power generation in Germany is covered by the EU Emissions Trading System. Through a system of tradeable emission allowances, this system limits the total amount of emissions from covered emitters in any given year for the entire EU. Thus, a decision to close down German coal-fired power plants could mean that more allowances are available to emitters elsewhere in Europe. To counter this effect (known as the "waterbed effect"), the commission recommended that Germany should cancel allowances corresponding to the emissions of the retired plants.

Figure B10:
Overview of the recommendations of the Commission on Growth, Structural Change, and Employment

A Phase out coal	B Support transformation of traditional mining regions	C Modernise the power system	D Alleviate hardship for those concerned	E Monitor and adjust measures
No more new coal-fired power plants and mines	Create new jobs and value added by investment and modernisation of infrastructure, research and innovation	Safeguard emission mitigation with more renewables, CHP and cancelation of CO_2 certificates	Mantain competitiveness of industries and affordability for households with power price compensations	Monitor and report progress in 2023, 2026, 2029 and 2032
Shut down existing plants step by step until 2035 or 2038 the latest	Indemnify recultivation of lignite mines	Ensure security of supply with monitoring, reserves and new capacity	Compensate utilities for early shut downs	Take additional action if needed
		Make the power system more flexible with more grids and storage	Ensure a 'Just Transition' for employees with active labour market policies	
			Conduct dialogue with resettlement affected near lignite mines	

Agora Energiewende (2019)

5. Implications for energy policy

The recommendations of the coal commission furnished a roadmap for overcoming one of the most contentious issues hindering further progress in Germany's energy transition. The roadmap was of particular value because it identified a compromise solution that was accepted by all major stakeholder groups. Importantly, the commission described not only how the coal phase-out should be implemented, but also how the process should be embedded in the broader effort to modernize Germany's energy system and transition to renewables without endangering energy affordability or security of supply.

5.1 Reception by political actors and key stakeholders

The commission's recommendations garnered broad support across the political spectrum. While it was perhaps not surprising that the reigning governing coalition and the ministerial heads welcomed the agreement, the opposition parties also largely accepted the outcome despite criticizing priorities and details.

Some major stakeholder groups, however, were highly critical of the agreement. Environmental groups and some academics criticized the long timeline for the phase-out as insufficiently ambitious, arguing that Germany's commitments under the Paris agreement required a much faster exit (Scientists for Future, 2020). A faster exit was seen as not only necessary for the climate, but also feasible from a technical perspective (Oei et al, 2020). Academic economists, by contrast, viewed the commission's recommendations as unnecessarily expensive, arguing that a meaningful carbon price would lead to a quicker, cheaper, and more efficient phase-out (Löschel et al., 2020). Critics also noted that a core aspect of the phase-out – its contribution to Germany's climate goals – was subject to significant uncertainty due to unclear provisions regarding the cancellation of ETS allowances (Pahle et al., 2019).

The recommendations of the coal commission also attracted international attention, although Germany was not the first EU country to announce plans to phase out coal. Austria, Belgium, Denmark, Finland, France, Ireland, Italy, the Netherlands, Portugal, Sweden, and the UK had all previously announced a coal exit – in all cases prior to 2030 (Europe Beyond Coal, 2020). Yet in contrast to other countries, Germany would be the first to leave significant amounts of commercially competitive coal in the ground (other nations would merely cease imports). In addition, Germany's solution of setting up a multi-stakeholder commission was highlighted as a model for reconciling divergent and entangled interests (Reitzenstein and Popp, 2019).

5.2 Market developments since the adoption of the recommendations

Implementation of the commission's recommendations began at the end of 2019. As history would have it, 2019 marked a massive and unprecedented decline in coal use in Germany and in other countries. The decline was attributable not to the implementation of the Commission's recommendations (which were delayed well into 2020), but to a number of other developments – in particular the rising carbon price, falling prices for natural gas, falling primary energy demand, and further growth in generation from renewables.

In 2019, power production from lignite fell by 22 per cent compared with 2018, continuing a trend of falling production over the previous six years. Power production from hard coal decreased year-over-year by 31 per cent, continuing a seven-year trend. At the same time, electricity generation from natural gas and from renewables both increased by more than 10 per cent (AG Energiebilanzen e.V., 2020).

The underlying causes – lower natural gas prices, higher renewable capacity, falling power demand, and higher carbon prices – meant that fewer and fewer coal power plants in Germany could operate profitably, particularly older and less efficient ones. By 2018, 2.3 GW of hardcoal capacity and 2 GW of lignite capacity had been placed in reserve. (While the operators of these plants had applied for shut down due to non-profitability, they were placed in reserve for reasons of grid stability). In 2019, two more lignite blocks and one hard-coal block entered the reserve system (Hein et al., 2020).

In a particularly contentious development, the Datteln IV hard-coal CHP plant represented an exception to this broader trend. While the commission had recommended that no new hard coal or lignite power plants be placed in operation, Datteln IV was not considered a new plant within the meaning of the agreement. It had been under construction since 2007, and had already received relevant permits. After the government failed to reach an agreement with the operator, Datteln IV went online in May 2020, adding 1.1 GW of power capacity and 380 MW of heat.

5.3 Subsequent political developments

Following the publication of the commission's recommendations, climate issues continued to play a prominent role in political debates. Throughout 2019, the student climate movement Fridays for Future attracted an ever-larger following, culminating in the climate strike of 20 September 2019, in which 1.4 million people took to the streets in Germany alone. Coinciding with this, the issue of climate change rose in the polls. (Germans continue to identify it as the single most pressing problem, even since the outbreak of the Coronavirus pandemic.) In this way, the climate debate continues to be driven by a groundswell of civil society opposition.

The rising prominence of the climate issue was also reflected in political developments. In September 2019, Germany's government announced a "climate package", a set of instruments to ensure that Germany would achieve its climate targets for 2030 and beyond. This package included a Climate Action Programme, a set of individual measures for implementing the coal phase-out, for promoting renewables and e-mobility, and a national carbon price for households and transport. In addition, the package included a "national climate law", which would enshrine into law the sectoral targets of the 2016 climate protection plan, including a pathway for power sector emissions consistent with the commission's recommendations. The package was adopted on 18 December 2019.

Then, in early 2020, EU Member States agreed to reduce their emissions 55% below 1990 levels by 2030, a stark increase from the previous 40% reduction target. Member States also agreed to a fundamental overhaul of EU climate policy architecture, including a more prominent role for carbon pricing. While the EU does not have the authority to regulate which energy sources Member States use, let alone how long they can continue to use coal, the scenarios for a 55% emission reduction leave little doubt: an analysis of the EU Commission's own modelling suggests that, to achieve the 55% target, coal cannot account for more than 2% of the EU's power production. This means that, of the 470 TWh generated from coal today, only about 50-60 TWh would be left in all of the EU (Meessen et al., 2020). Ergo, the German phase-out plan is incompatible with the increased ambition expressed in the EU's 2030 target.

5.4 Nuclear phase-out

While the commission regarded the impact of the coal phase-out on power system reliability as manageable, the need to closely monitor security of supply was generally acknowledged, particularly in light of Germany's plans to simultaneously phase out its last six nuclear power plants (representing 8.1 GW) by 2022. The nuclear phase-out thus coincides with the first wave of the coal phase-out. Taken together, this amounts to a significant shutdown of assured generation capacity. The loss was initially seen as less problematic, since Germany had accumulated a sizeable surplus of generation capacity in previous years, driven mostly by growth in renewable capacity.

6. Active steps and open issues as of December 2020

The commission's final report was deliberately written as a roadmap for political implementation, including recommendations for specific institutional, legal, and regulatory changes. As the final report was the outcome of contentious and intricate negotiations between key stakeholder groups, the commission urged the federal government to adhere closely to its recommendations when implementing the phase-out.

Steps to implement the commission's regional-development and climate policy recommendations began promptly following the presentation of the final report:

- In August 2019, the Ministry of Economics and Industry tabled a draft law on "structural support for coal-mining regions" (Strukturstärkungsgesetz Kohleregionen). The law was designed to implement the commission's recommendations related to regional development in the coal-mining areas, to facilitate a transition away from coal. The draft law envisioned allocating up to 14 billion euros in grants to the three lignite mining regions. These grants would be made available for various forms of infrastructure investment, from public services and transport to telecommunications and research. In addition, the federal government committed to make up to 26 billion euros available to the regions through federal investment programmes (e.g. for research and development) and to accelerate federal infrastructure investment, particularly in transport. To administer the funds and to ensure their rapid deployment, a high-level body is to be established, composed of federal and state representatives. The law on structural support for coal-mining regions was ultimately adopted by both houses of parliament on 3 July 2020.
- The legal basis for the coal phase-out (the Kohleverstromungsbeendigungsgesetz, or KVBG) was presented as a first draft in November 2019 by the Ministry of Economics and Energy. As proposed by the commission, the draft envisioned separate procedures for managing the shutdown of hard-coal and lignite plants. In competitive bidding process, the operators of hard-coal plants would submit bids, offering to take their plants offline in return for a given level of compensation from the government. By contrast, the government would negotiate compensation arrangements on an individual basis with the operators of lignite power plants and mines. A specific timeline for phasing-out the lignite plants was ultimately reached in January 2020 following negotiations between the federal government, relevant state governments, and utility companies. This agreement included details regarding specific compensation amounts. Following several rounds of deliberation, the law on phasing-out coal use was eventually adopted by both houses of parliament on 3 July 2020, together with the law on structural support for coal mining regions.

Germany has thus made firm legal commitments to end the use of coal by 2038 at the latest. With the passage of the aforementioned laws, various adjustments were also made to other energy-related laws, such as the combined heat and power act (KWKG) and the renewable energy sources act (EEG). The coal phase-out schedule has been further enshrined into law by various policy enactments, including the Climate Action Programme of September 2019, and the German Climate Change Law of December 2019.

The coal phase-out law directly incorporates the agreements reached with lignite mine operators concerning the timeline for closure and the associated compensation. Importantly, voluntary closure ahead of schedule does not reduce compensation.

The coal phase-out law also introduces an annual auction mechanism for the closure of hard-coal power plants. The amount of capacity eligible for shutdown compensation is defined for each year; the law also sets a cap for compensation per MW. This cap declines over time, from 165,000 euros per MW in 2020 to 89,000 euros per MW in 2027.

The first auction was held in August 2020. 11 bids for the shutdown of 4.8 GW of coal capacity were accepted by Germany's grid regulator. The auction closed with an average payment of 66,259 euros per MW, with bids as low as 6,047 euros and as high as 150,000 euros per MW. A second auction was held in April 2021, subject to a decreased cap price of 150,000 euros. The auction awarded contracts for closure of three units with a total of 1,514 MW and closed with a maximum bid of 59,000 euros per MW and an inferior bid of zero euros per MW. The next auction will take place in October 2021 and auctions will be repeated on an annual basis until 2030. Thereafter, any remaining plants will be closed without compensation. The grid regulator also has a right to force plant shutdowns without compensation if plant operators fail to submit bids for a sufficient volume of capacity. In this way, the auction mechanism is designed to encourage operators to retire their plants sooner rather than later. The mechanism also features provisions to prevent collusion and market abuse. These provisions will become particularly important in future years, as the number of remaining plants shrinks, thus augmenting the risk of collusive bidding behaviour. Upon the publication of the energy phase-out law, the European Commission investigated the bidding process to retire hard-coal plants, and explicitly approved it as being in line with EU state aid rules. This finding did not apply to the compensation payments that were individually negotiated with the operators of lignite plants. In this connection, the EU Commission launched an inquiry to ascertain whether the agreements breach state aid rules, which could jeopardize the agreed compensation payments.

The end of 2020 saw the first closures of coal plants because of the agreed coal phase-out. For lignite plants, the effect was modest: only one relatively small, 300 MW unit was shut down (Niederaußem D). According to the agreed schedule, the next three lignite units (all in the west of Germany), with a combined capacity of 900 MW, will close by the end of 2021. For hard coal, the first auction round in September 2020 resulted in the closure of 11 coal plants with a combined capacity of 4.8 GW at the end of 2020. Notably, this included 1.6 GW from both units of the Moorburg plant in Hamburg, which had come online only five years prior. The second auction took place in January 2021 and resulted in the closure of three coal-fired power plants, with a total of 1.5 GW. Several aspects of the coal phase-out law have been criticized by the media, stakeholders, and other experts, including former commission members:

- Divergence from the recommended phase-out path: While the phase-out law specifies coal capacity targets for 2022, the end of 2030, and 2038 (the end point of the process), it does not lay down interim targets for the period between 2022 and 2030. The law also fails to provide for a significant reduction in capacity by the mid-2020s. At the time of the agreement, the recommendation for significant closures by the mid-2020's was understood to refer to plants in the region of Lusatia. However, these plants are now scheduled for closure in 2028, with the option to place one unit in reserve earlier. As several critics have observed, deviation from the commission's recommendations will lead to higher emissions than those of a steady reduction path, as the closure is delayed by several years. This creates a situation in which significant capacity is shut down early (before the end of 2022), followed by several years of slow progress, prior to another burst in closures in 2028 and 2029, creating unnecessary risks for the stability of the power system.
- Excessive compensation for lignite-fired power plants: Media reports as well as expert assessments have criticized the compensation amounts granted to the operators of lignite-fired power plants, arguing they are excessive and possibly inconsistent with state aid rules. Squeezed by high carbon prices, cheap natural gas, and low electricity prices, the plants in question were barely profitable or even running losses in most of 2019 and 2020; indeed, at least one plant (Lippendorf) was taken off the grid in 2019 for economic reasons. As a result, the compensation amounts appear inflated, as they are difficult to justify in terms of foregone profits or lost asset value (Matthes et al., 2020).
- The debate surrounding Datteln IV: The law bans the construction of new coal-fired capacity. Importantly, though, this does not include plants for which an operating permit had already been issued prior to January 2020. In effect, this applies to one plant only – Datteln IV, an 1,100 MW hard-coal unit in the West of Germany, which had been in construction since 2007, but had experienced significant delays. After the government's failure to reach an agreement with the operator of Datteln IV, the plant came online in May 2020, thus sending mixed messages about Germany's commitment to phasing-out coal.
- Unclear rules for ETS allowance cancellation: In order to offset the "waterbed effect" (see footnote 5), the commission recommended that Germany make use of the EU ETS mechanism for removing emission allowances permanently from the market, in proportion to the avoided emissions from coal. Critics have argued that the phase-out law fails to stipulate binding cancellation amounts, and the calculation method laid out in the law will not remove enough emission certificates from the market.

- Failure to acknowledge changing conditions on the ground: Despite the above exceptions, the phase-out law largely follows the recommendations of the commission. But according to critics, the law fails to account for changing conditions since the adoption of the commission's final report. Rising allowance prices in the EU ETS in combination with low natural gas and electricity prices have rendered much of Germany's coal power plant fleet unprofitable. Furthermore, numerous countries have since announced plans to phase out coal on a much faster timetable, including most of Germany's neighbours. But above all, the increased ambition expressed in the EU's emission reduction target for 2030 means that, across Europe and its sectors, emissions will need to be reduced more aggressively than previously foreseen – and this includes Germany's coal phase-out. Critics have thus argued that recent developments have created room, but also a need, for a more ambitious phase-out.

Section C – Comparative analysis and conclusions

1. Comparative analysis of coal phase-out in Chile and Germany

1.1 Comparing the socio-economic structure of Chile and Germany

When comparing Chile and Germany, we see strong differences, as well as some interesting commonalities, as illustrated by the indicators summarized in Table C1.

One difference is that Chile has more than double the land area of Germany, but only a fifth of its population. As a result, Germany's population density is close to ten times higher than that of Chile. When it comes to economic development, Germany's GDP per capita is close to four times that of Chile and its GDP is 16 times larger. While this difference is partially explained by relative population size, it is important to recognize that Chile is still an emerging economy with a relatively lower Human Development Index, higher social inequality (as measured by the Gini index), and higher unemployment. Chile's economy is also less diversified, with 13 per cent of its GDP related to mining (mainly of copper) and only 12 per cent to other industries.

Despite these stark differences, both countries have a similar and comparably low debt to GDP ratio, and show a healthy level of gross domestic savings and a relatively high competitiveness index, all of which corroborate their favourable investment climate.

Another commonality is that both Chile and Germany are very dependent on energy imports. While Germany's primary energy demand per capita is higher (165 GJ versus 92 GJ), its dependency on energy imports is high (64 per cent) but more moderate than the very high dependency of 91 per cent for Chile (2019). While coal represents around 20 percent of primary energy demand in both countries, about half of Germany's coal is produced domestically, while Chile is fully dependent on imports.

In both countries, the expansion of domestic renewable energy sources is an important and powerful strategy for reducing dependency on fossil fuel imports. In addition to substituting fossil-based electricity generation, this will require the electrification of transport, heating, and industry.

Another important strategy for reducing energy dependency is to increase the efficiency of economic activities. Germany, for example, has grown its GDP by 54 per cent and reduced its primary energy consumption by 14 per cent since 1990. In the same period, Chile has shown an even more impressive economic growth of 370 per cent. The fact that its energy consumption grew by only 139 per cent shows that the energy efficiency of the economy has also significantly increased.

Both the German and Chilean power sectors had a comparable share of renewables in 2020, comprising 44 and 46 per cent of generation, respectively. In Chile, traditional hydropower plants – most of which were built in the last century – are still the largest source of renewable electricity. Biomass, which has a significant share of nine per cent in Germany, makes only a limit contribution of two per cent in Chile. In Chile, wind and solar have grown significantly in the last decade, with solar now comprising ten per cent of total power production. (By contrast, the solar share is ten per cent in Germany.) Solar capacity in Chile is dominated by a relatively low number of large-scale installations that are connected to the high-voltage transmission grid, while Germany has built its generation capacity with about two million small solar systems that are connected to local distribution grids. Chile's wind power generation, which has a share of seven per cent, is still well below the 19 per cent onshore wind share observed in Germany. However, both wind and solar are particularly competitive in Chile and are poised to grow rapidly in the coming years. Given existing large hydropower capacity, this expansion will lead to the swift, market-driven substitution of coal power.

While Chile's large hydropower capacity is a distinct advantage, not least due to its ability to flexibly complement variable wind and solar generation, the optimisation, backup, and balancing of Chile's power system is severely limited by its geographic characteristics and isolation. Compared with Germany, Chile has an immense endowment of high-quality renewable energy resources, particularly solar in the north, as well as wind, hydropower, and potentially biomass in the south. However, the development, integration, and management of these resources are impaired by their allocation at the northern and southern extremes of the country, which stretches over 4,270 km, with an average width of 175 km. Moreover, the Chilean power system is relatively small, and largely isolated from neighbouring countries.

In contrast, the German power system is seven times larger and fully integrated with its European neighbours, which facilitates the balancing of higher feed-in from variable renewables.
While this difference in system size and integration is decisive for our discussion, it must be mentioned that, in principle, both countries have relatively similar liberalized electricity markets, even if their regulatory approaches to incentivizing the energy transition have been fundamentally different.

To understand this point of difference, it is important to recognize the divergent contexts in which the energy and climate strategies pursued by Germany and Chile have evolved. German is an established economy. It is an Annex I country in the United Nations Framework Convention on Climate Change (UNFCCC), which was ratified in 1992 and entered into force in 1994. As a result, Germany, together with other Annex I countries, agreed to take the lead in combating climate change. With this commitment, Germany undertook early policy

Table C1: Socio-economic indicators for Chile and Germany in 2019

Indicator	Chile	Germany
Population size (millions)	19.5	83.2
Land area (km²)	756,102	357,582
Population density (number of inhabitants per km²)	25	232
Gross Domestic Product (billions of U.S. dollars)	289	4,659
GDP per capita (USD / per capita)	15,126	56,085
Debt / GDP	68%	70%
Gross domestic savings as % of GDP	19%	10.9%
Most relevant economic sectors (% GDP)	Services: 39%* Mining: 12%** Industry: 12%***	Manufacturing: 24.2% Public services: 18.8% Services: 16.2%
Unemployment rate (% of labour force)	7.2%	3.2%
Gini coefficient (between 0=complete equality and 1=complete inequality)	0.49	0.29
Human Development Index (HDI)	0.85	0.94
Competitiveness index (score out of 100)	70.5	81.8
Energy dependency (net imports / gross available energy, 2018)	91%	63.6%
Primary energy per capita (GJ/p.c.), 2018	92	165

OECD Statistics (2020), Volkswirtschaftliche Gesamtrechnungen, WEF (2019), p. XIII, Eurostat (2020), The Global Economy (2020), Banco Central de Chile (2020), WEF (2019)

* Includes Antarctic continent.
** Value considers the total population and the continental territory.
*** Value reported in 2018.

action to substitute fossil fuel-based power generation and to promote wind and solar at a time when these renewable technologies were still relatively expensive.

Chile, on the other hand, is part of the developing country group (Non-Annex I), which, according to the UNFCCC, has economic and social development and poverty eradication as first and overriding priorities. When it faced energy shortages linked to the reduced supply of natural gas from Argentina in 2008, Chile understandably opted for the expansion of coal-based power generation instead of renewable alternatives, which were still very expensive and still widely considered unreliable by stakeholders at the time. While a few wind projects were developed during this period, their financial viability was based on the international Clean Development Mechanism (CDM), an international support mechanism. However, this mechanism quickly faltered and failed to justify continued large-scale renewable energy deployment. As a result, over the last 15 years, Chile increased its coal-fired generation capacity by 3.7 GW, an amount equivalent to 75 per cent of total installed capacity today.

However, Germany also undertook significant recent investment in coal power, commissioning 10 GW of new capacity over the last decade. Both countries thus have significant coal-fired generation capacities with operational lifetimes that exceed the coal phase-out date defined by their respective coal commissions.

In hindsight, both Chile and Germany made large-scale investments in coal power that will become stranded assets long before they are financially amortized. In both countries, these investments took place in part because a decade ago, utilities did not expect such rapid declines in the cost of renewables. Given the stark change in the economic fundamentals for renewables development, both Chile and Germany recently adopted policies to facilitate the decommissioning of existing coal power plants, as well as to discontinue the construction of new ones, as discussed below.

Another difference to be considered is that Germany operates its own coal mines, while Chilean coal demand is met almost entirely by imports. As Germany's domestic lignite production can only be used locally and does not have an alternative use, this fuel is more competitive than hard coal, especially at existing plants with integrated mining operations. Moreover, Germany's integrated mining and power generation plants employ a significant number of workers, and thus play an important role in local economies. This complicates deliberations on the social and economic impact of their closure.

While these differences explain why a "just transition" and associated investment programmes for mining regions and workers have a more critical role in Germany than in Chile, it should be kept in mind that the phase-out of coal imports generates upstream impacts in exporting countries. Colombia, for example, which supplies coal to both Germany and Chile, will have to contend with the social and economic effects of lower coal demand from abroad.

1.2 Comparing driving forces for energy transition and coal phase-out

Each country internationally has a different starting point for the transition of its energy sector. Germany started early to subsidize renewable energy in order to promote technological development and associated cost reductions. A specific hallmark of Germany's transition was the widespread involvement of households, farmers and local energy cooperatives as investors in small-scale dsitributed systems at the level of the distribution grid.

Chile started its energy transition at a later date. Initially, the CDM was the only relevant subsidy for the deployment of renewable energy. However, in recent years, the cost of renewable technologies has dropped immensely on a global scale. While this has encouraged renewables development in all countries, it has had a particularly strong impact on Chile, due to the country's favourable investment climate and outstanding wind and solar resources – a combination that has proved very attractive to investors.

Another difference between both countries is that solar PV plants in Germany tend to be smaller, more decentralized and connected to local distribution grids. By contrast, large solar farms dominate in Chile; self-generation is minimal.

As evident in Table C2, Chile's excellent renewable energy resources in combination with its liberalized power market have been the main driving forces of its coal exit. However, the dynamic unleashed by these forces is relatively new. Growth in renewable energy was sluggish in the early 2010's. At that time, high energy prices attracted new coal investment, as coal was the most price-competitive energy resource. However, once the cost of renewables had dropped below that of coal, renewables investment in Chile's liberalized energy market surged tremendously. Indeed, even coal operators that had recently built coal-fired power plants based on long-term power purchase agreements saw an opportunity to source renewable energy at a cost below the variable cost of coal-based generation – and the associated profit margins were sufficient to compensate for the decreased utilization of their coal-fired assets. While this combination of low-cost renewables and a liberalized electricity market was fundamental, it must be recognized that Chile supported this movement to renewables with environmental rules and standards that increased the cost of coal-fired generation. Of special relevance is the carbon tax of 5 USD per tCO_2, as well as taxes and restrictions on local pollutants.

Table C2: Ranking of forces driving coal phase-out in Chile and Germany

	Driving forces in Chile		Driving forces in Germany
↑↑↑	Low-cost renewables & expensive coal imports	↑↑↑	RE incentives
↑↑↑	Liberalized power market	↑↑↑	EU ETS carbon price
↑↑	Environmental rules, standards & taxes	↑↑↑	Favourable EU grid integration and balancing
↑↑	Investor & public pressure	↑↑	Incentives for closure
↑↑	Green electricity demand for industry & hydrogen	↑	Investor & public pressure
↑	Favourable investment climate	↓↓	Cheap lignite
↑	Regional grid integration (SIC-SING)	↓↓	Interests of mining regions
↓	Lack of full regional grid integration	↓↓↓	Sluggish expansion of national grid

Source: Agora Energiewende

Furthermore, the movement away from coal and toward renewables has been supported by pressure from investors and the public at large. As many of Chile's coal power generators are international utility companies, pressure from local actors resonated with that of the global public. However, Chile's utilities also saw investment opportunities associated with phasing out coal, as the integration of renewables requires massive outlays in renewable systems and transmission infrastructure (e.g. to interconnect the central and northern electricity grids). There has also been increasing demand for clean electricity, especially from copper-mining and industrial actors. In addition, the rapid development of Chile's green hydrogen strategy, which includes numerous projects under development, has shown that coal phase-out is a necessary step to unlock significant and transformational economic opportunities for Chile's energy system and economy. This may even allow Chile to overcome the main obstacle to the full transformation and decarbonisation of its electricity system: namely, the fact that Chile has a small electricity grid and is isolated from its neighbours. One possibility is for Chile to provide electricity system backup and stabilisation services, possibly with the conversion of coal-fired power plants to innovative energy storage and balancing systems. Another option is to develop a hydrogen-based energy export economy. This would not only increase the scale and flexibility of Chile's power system, but also enable the country to shift from energy import dependence to an economy that exports renewable energy-based fuels and products.

The German energy transition started and continues to evolve in a very different context. From its outset to the late 1990s, Germany's transition was supported by strong policies for renewables expansion. Key promotional policies have included feed-in tariffs to promote renewable energy investment and the carbon pricing of emissions from fossil fuel generation (through the EU ETS). However, while these policies drove the development of renewables, they were ineffective in limiting the use of coal. Only in the mid-2010s, when it was clear that GHG emissions would not decline in line with national targets, did the coal exit begin to take centre stage in the public debate.

One reason why coal continued to dominate power generation in Germany was the low EU ETS carbon price. Once a comprehensive reform succeeded in raising the carbon price in 2018, hard coal generation started to decline. The trend toward lower coal generation continued in 2019 and accelerated further in 2020, abetted by a higher carbon price, low natural gas prices, and a low power demand due to the COVID-19 pandemic. For the first time, even lignite generation was no longer cost competitive for extended periods: After supplying roughly the same volume of power for 25 years, lignite-based power generation experienced a plummeted by of 22 per cent in 2019 and close to 20 per cent in 2020. As a result, even before the coal-exit negotiations began, several hard-coal power plants were shut down due to their unprofitability.

Lignite and hard coal differ not only in terms of their cost structure, but also in terms of their significance to the labour market. While Germany's last (heavily subsidized) hard-coal mine closed in 2018 after a phase-out process of more than 20 years, lignite mining in Germany continues to this day, and is responsible for the direct employment of some 18,500 workers (primarily concentrated in Germany's three coal-mining regions). By contrast, Germany's hard-coal plants are responsible for between 4,000 and 8,000 jobs (which are widely spread across the country).

1.3 Comparing the process, structure, role & recommendations of the coal commissions

The German and Chilean coal commissions illustrate the importance of constructive stakeholder engagement to balance conflicting interests and achieve consensus when it comes to planning the terms of a nationwide coal phase-out.

In both Chile and Germany, coal phase-out deliberations were launched in early 2018. While the initial results were presented at the COP 2018, the process did not conclude until January 2019. In Germany, the work of the coal commission was important for addressing the country's looming failure to meet its GHG reduction targets for 2020. As Germany's recently elected coalition government could not agree on the path forward, their coalition agreement signed between the CDU and SPD appointed the coal commission as an independent stakeholder forum, and mandated it with assembling the consensus needed to overcome conflicting interests on this divisive topic.

In Chile, the creation of the coal commission was triggered by its bid to host the COP 25 and take a more proactive role in multilateral negotiations. However, the decision to form the commission was crucially abetted by the rapid rise in the competitiveness of new renewable energy systems. In this way, the Chilean government and the country's energy utilities recognized that the coal phase-out was inevitable, and that proactive steps were needed to manage the attendant structural change.

As a result, Chile's coal commission differed from Germany's in terms of its composition and political nature. Chile's commission was not only a forum for stakeholder dialogue, but also for direct exchange between the reigning government and private sector – actors that did not have a direct role on the German coal commission. As a result, the Chilean commission arrived at a rather general agreement between government and the private sector, in which many details were left undefined. For example, the agreement called for the decommissioning of some old and fully depreciated coal power plants in the short term, and also defined 2040 as the goal year for fully exiting coal, but it did not set forth an exact path for the gradual closure of the country's plants. The absence of a precise timetable is explained in part by Chile's traditional commitment to laissez-faire economics.

Similarly, the Chilean agreement addressed social concerns and impacts, but compared with Germany, less ambitious provisions were adopted to assist affected communities and workers. This is because, in Chile, only a few municipalities in the region of Tocopilla are affected by the shutting down of coal-fired plants, while in Germany, the transition impacts two regions, the Rhineland and Lusatia.

In Germany, the coal commission was designed to be independent from direct political and private sector influence. It had the objective of building a consensus on all critical economic and social issues, a consensus that could serve as a blueprint for the legal implementation of the coal phase-out. Accordingly, the findings only took the form of indicative recommendations for the government to act. These recommendations were in many respects very detailed, especially where stakeholders had managed to achieve recognition for their specific interests. One example is the coal commission's earmarking of specific financing volumes to support affected regions, communities, and workers. The definition of mechanisms to compensate plant and mine operators for the early decommissioning of their assets is another example of the precision shown in the German recommendations. In contrast to Chile, Germany showed no hesitation to engage in the type of industrial planning that overrides market forces, which was seen as necessary for accelerating the closure of coal-fired power plants and reaching compensatory agreements with operators.

However, there were also aspects that were kept vague, in order to find common ground for consensus. In both Germany and Chile, rather than defining a concrete pathway for plant closure, a decision was reached instead to define the MW volumes that would need to be shut down in the short term, in addition to the adoption of a specific exist year (in Germany, 2038). In addition, the Germans identified a 2030 milestone to assure interim progress.

Table C3: Chilean and German coal commission recommendations and their implementation

Aspects	Key recommendations in Chile	Key recommendations in Germany
Coal phase-out plan & climate targets	• No new coal power plants without CCS. • Close existing plants by 2040 plus short-term closure of 8 plants (19% of total) before 2024. • Additional plant closures announced as part of shutdowns by 2024. • Chile is developing a Framework Law on Climate Change and a Long-Term Climate Strategy to accelerate the process.	• No new coal power plants or mines. • Close existing plants by 2038 at latest with intermediate targets for closure of 11 GW by 2022 (-27%) & 24 GW by 2030 (-58%). • Recommendations of the coal commission have been implemented with various legal acts. • Beginning in 2020, the EU adopted an ehanced emission reduction target of 55% for 2030, which implies accelerating the coal exit in Germany.
Support for affected regions & communities	• The conversion of coal-fired power plants to new activities is seen as an opportunity to create jobs. • Recommendations for community engagement and labour market policies. • Recommendation for the government to create a Just Transition Strategy.	A budget of 40 billion euro was recommended to support affected regions over 20 years to: • Create jobs and value added by investing in infrastructure, research, and innovation; • Provide pension schemes and labour market support for affected workers; and • Provide insurance for covering costs of coal mine recultivation.
Compensation for plant & mine operators	• Payments granted for five years for plants with Strategic Reserve Status. • Agreements to explore the conversion of existing plants to other uses.	• Negotiated compensation for early closure of lignite mines and power plants. • Auctioning of contracts for closure of hard- coal mines.
Modernize the power system	• Twenty-year plan for significant expansion of renewables and the transmission grid (thus generating significant investment costs, which will be partially offset by lower operational costs. • Ensure security of supply by monitoring the process and implementing corrective steps necesary. • Higher investments that are justified by benefits in terms of job creation and reduced health impacts.	• Safeguard emission reductions by expanding renewables and CHP plants. • Cancellation of emission allowances to avoid ETS waterbed effect. • Ensure security of supply by monitoring the process and implementing corrective steps as necessary. • Implement measures to flexibilize the power system with more grid and storage capacities.
Mechanisms to monitor and adjust outcomes	• Agreement and recommendation that more research is required to manage coal phase-out to avoid, mitigate, or offset social impacts. • The Ministry of Energy and Environment is developing a Just Transition Strategy to address socio-economic programs and environmental criteria.	• Regular monitoring and reporting of progress, with adjustment measures if needed. • The Federal Network Agency has oversight, and all power plant closures are subject to its approval (to ensure the stability of the energy system).

Source: Agora Energiewende

1.4 Implications and outlook for energy policy

In both Chile and Germany, the conclusion of the coal commission marked the end of a controversial process, and, simultaneously, the start of a new, accelerated phase of the energy transition. Initially, many stakeholders applauded the commissions' work as an important example of consensus building. Many others, however, criticized the agreements as lacking sufficient ambition.

In both countries, the coal exit commissions formulated a common perspective on critical aspects of the coal phase-out. This resulted in a new dynamic with impacts beyond the implementation of the agreements.

As a key element of this dynamic, coal phase-out is conceived as a necessary condition for the transformation within the power sector and beyond, including the electrification of transport, heating, and industry. Using electricity to replace fossil fuels only makes sense if the electricity in the grid is abundant, and predominantly renewable. Moreover, flexible electrification in other sectors allows one to increase the share of renewable energy in the system, and improve its balancing, among other benefits.

In Germany, the accelerated electrification of transport illustrates the strategic importance of Germany's coal phase-out for the economy. At long last, Germany's auto manufacturers are striving to position themselves as leaders in the development, manufacture, and sale of battery-electric vehicles. However, both the energy intensive production of batteries as well as their regular charging requires large amounts of electricity, and only makes sense in an electricity system that is dominated by renewables and no longer relies on coal.

Another prominent example is the production and use of hydrogen. In Germany, this is a key element of planning for the decarbonization of industry. Yet developing hydrogen economies makes sense only in a system that is dominated by renewable energy. Accordingly, a coal phase-out is a necessary precondition. Many of the coal power plants slated for closure offer compelling sites for the development of hydrogen-based industrial hubs. For example, the coal-fired power plants in Wilhelmshaven (757 MW; closure scheduled for December 2021) and Moorburg (1600 MW; closure in December 2020) are envisaged as future locations for hydrogen-based industry. As both locations have port facilities, local hydrogen production can be complemented with foreign import by ship. These development plans are founded in Germany's national hydrogen strategy, which was adopted in June 2020. The strategy foresees building 5 GW of domestic hydrogen production by 2030, with supplemental hydrogen imports, given Germany's limited renewable energy development potential.

In Chile, comparable developments have taken place. In November 2020, the country published its Green Hydrogen Strategy, developed with support from GIZ. In comparison with its German equivalent, the Chilean Green Hydrogen Strategy is very ambitious, not least due to the country's excellent endowment of renewable energy sources. Like Germany, Chile aims to develop 5 GW of electrolyzer capacity, but wants to have these facilities in operation or under construction by 2025. Chile also hopes to become a leader in the global green hydrogen market by 2030. Given that Chile's renewable energy potential dwarfs that of domestic demand, seeking to become a net exporter of hydrogen and hydrogen-based fuels is a natural choice. Chile is thus slated to become an important partner to Germany and other countries that will depend on the import of renewable energy-based fuels and products. Like Germany, Chile views several of the coal-fired power plants slated for closure as potential sites for hydrogen production.
To seize the direct and indirect benefits of electrification within the context of a coal phase-out presupposes the further expansion of renewables capacity. From 2019 to 2020 renewable energy capacity in Chile grew by a record 11 per cent; growth in Germany was more modest, at 5 per cent.

At the same time, important developments in climate policy have taken place in Chile, Germany, and Europe. Building on the goal of a coal exit by 2040, Chile is now targeting a climate-neutral power sector by 2040 and a climate-neutral economy by 2050 in its revised NDC. Moreover, Chile is preparing important legislation to enhance and consolidate its climate policies, including a Long-Term Climate Strategy and a Framework Law on Climate Change.

Similarly, Germany has revised and enhanced its energy and climate policies. In addition to the adoption of a Coal Exit Law in August 2019, Germany introduced a Climate Protection Law in December 2019. At the EU level, Germany has also agreed to an enhanced GHG abatement target of -55 per cent by 2030, which is the basis for the bloc's revised NDC that is to be presented at COP 27.

However, on April 2021, Germany's Constitutional Court declared the German Climate Change Act of 2019 as partly unconstitutional. The judges found the previous law shifts the burden of reducing GHG emissions to future generations, directly threatening the future exercise of their constitutional rights to freedom. Cabinet approved a reform of the country's Climate Action Law that includes stepping up the 2030 target for emission cuts to 65 from 55 percent, tougher emission budgets in all sectors, new reduction targets for the 2040s, aiming climate neutrality by 2045. The changes in the law still need to be approved by parliament before they take effect.

Given the multitude of commitments to the energy transition and achieving a climate-neutral energy system, almost all market actors have been persuaded to embrace change, and have been developing their strategies and business plans accordingly.

A striking fact in both Chile and Germany is that the phase-out is proceeding ahead of schedule. In Chile, this is a market-driven process that has led utilities to announce plant closures sooner than originally foreseen, due to unprofitability. Moreover, there are also examples of market actors that previously signed contracts for coal power-based generation, but are now paying to end such power purchase agreements long before their original end date. Moreover, investors have been keen to finance the replacement of coal-based facilities with renewable power systems.

In contrast to this market driven approach, Germany has implemented auctions that allocate compensation for closure. Germany held its first auction in September 2020 for the closure of 4,000 MW of coal capacity, and a second in January 2021 for the closure of 1,500 MW. In both auctions, the volume of capacity bid for shutdown exceeded the offered capacity.

In addition, coal power plants were barely profitable or even operating at a loss in 2019 and 2020 due to a combination of high carbon prices, cheap natural gas, and low electricity prices. Notably, this applies not only to hard-coal units, but also to lignite power plants; at least one lignite-fired plant (Lippendorf) was taken off the grid in 2019 for economic reasons.

With such promising developments in both Chile and Germany, observers anticipate a more rapid exit than currently targeted by each country's coal commission. However, the accelerating phase-out also brings certain challenges:

1. An accelerated coal exit implies faster structural change for workers and regions that depend on coal mining and power generation activities.
2. The speed of coal-phase out is limited by the expansion of renewable generation capacities and their grid integration.

The expansion of renewable energy capacity is an important factor in Germany and Chile. However, Chile also faces the need to expand its transmission grid and ensure security of supply. Notably, Chilean plans to develop hydrogen production and export could mean a growing strategic link to Germany. In Chile, a robust hydrogen economy would help to propel renewable energy development, power grid expansion, and the electrification of other sectors. At the same time, Germany would gain an additional trading partner for green energy imports, which will be crucial as a supplement to domestic renewables production.

2. General conclusions

Our foregoing comparison of the coal-exit strategies developed by Chile and Germany illustrates the inevitability of phasing out coal when climate change commitments are taken seriously. By extension, the decision to phase out coal necessitates the decarbonization and electrification of the energy system as a whole. But beyond climate policy ambition, another important driver of coal phase-out has been the rapid decline in the cost of renewable energy, and the economic opportunities of its development.

Our comparison has shown that various domestic factors need to be taken into account when designing coal phase-out policies, including natural resource endowments, economic conditions, and political and regulatory frameworks. Based on this domestic context, strategies should be devised that maximize benefits and minimize social and economic dislocation. With the interest of supporting other countries in defining their own approach, we offer the following general conclusions:

1 Phasing-out coal is an inevitable but significant structural change that must be managed carefully while involving stakeholders from affected regions.

The early and comprehensive engagement of relevant parties enables the reconciliation of divergent interests, the definition of adequate measures for a just transition, and the recruitment of solid stakeholder support.

While the economic benefits of a well-managed coal phase-out is a boon to society at large, it also imposes a profound structural change on investors, regions, and populations that are involved in coal mining and power generation. Due to their diverse vested interests, the discussion can easily become divisive. A coal commission can provide an adequate platform for inclusive deliberation, and thus offer a way to reconcile different interests, achieve lasting stakeholder support, and ensure broad economic benefits.

An important outcome of the German commission was that it forged a broad and robust compromise among a range of stakeholders, each of whom came to the table with very different objectives. As the commission was formed, the future of coal mining in Germany had the potential to develop into a bitter, divisive, and drawn-out societal conflict in which the interests of utilities and coal miners were pitted against those of the climate movement. Through its broad and inclusive approach, the commission identified a way forward that would be acceptable to all sides and would thus allow the federal government to move forward with the support of the main stakeholder groups.

In the case of Chile, the situation was different in two significant aspects. First, the country has minimal coal-mining activities, a fact that reduces the social impact of the coal phase-out to power plant employees in just a few locations. Second, the coal phase-out in Chile is largely driven by economics: the declining competitiveness of coal-based generation in the face of enormous potential for the development of cheap renewable energy led utilities to transform their business models. Thus, while the starting point for the Chilean process was different, in both German and Chile the inclusive and comprehensive dialogue implemented by the coal commission was essential for discussing the implications of the coal phase-out among stakeholders and for developing solutions to manage economic and social impacts.

In coal-mining regions, the coal phase-out implies a profound structural change – but with adequate support, it can also represent an opportunity to transition to a more diversified, future-proof economy.
A phase-out plan needs to acknowledge that the closure of coal mines and power plants represents a massive disruption for employees, utility companies, dependent industries, and

local communities because it threatens jobs and regional value chains. But with adequate support structures, it can also represent an opportunity to build a more diversified, future-proof economy. Managing the process must include the engagement of local stakeholders to develop strategies that have local support and minimize resentment, conflict, and potentially unrest.

In this way, an effective coal phase-out strategy must include policies for transitioning the labour market and regional development, for promoting sustainable economic alternatives for affected regions, and for providing coal industry employees with new skills and job opportunities. But while employment and income are key factors, they are not the only ones: the transition process also affects regional identities and culture. Giving a voice and visibility to affected groups is therefore an important part of the transition process.

Both Chile and Germany have embedded their coal phase-out plan in a broader strategy for alleviating social hardships and assisting affected regions. A key difference, however, is that the impacts in Germany are much more concentrated in regions where coal mining takes place. The fate of these regions and their outlook has thus played a much greater role in the deliberations. While in Chile, the economic support measures to affected regions will be determined for each case individually, Germany formulated a transition strategy for each coal region, complete with a concrete set of measures and guarantees of financial support and other forms of transition assistance.

2 Substituting coal with renewable electricity is essential for direct and indirect electrification strategies that transform national and international energy markets.

Sound energy planning and an effective and adaptive policy framework that focuses on supply- and demand-side flexibility are needed to ensure the success and efficiency of the process.

In countries like Chile and Germany, which have limited domestic fossil energy resources, the expansion and use of domestic renewable electricity generation is not only a strategy to reduce greenhouse gas emissions, but also an opportunity to reduce fossil-fuel import expenses. However, achieving greater energy independence based on renewables requires integrated markets and sound planning.
With well-designed policies and regulations, countries can expand energy generation and power grids to satisfy direct and indirect electrification in transport, heating, and industry, while also ensuring security of supply, energy affordability, minimal environmental impacts, and public approval.

However, some countries such as Germany have limited renewable energy endowments and will continue to depend on supplementary energy imports. With the objective of carbon neutrality in sight, these energy imports should take the form of green hydrogen and hydrogen-based fuels. For countries with abundant renewable energy resources, such as Chile, the coal phase-out represents a path to complete decarbonization, with the potential to complement the domestic energy system with the export of hydrogen and hydrogen-based fuels. The case examples furnished by Chile and Germany illustrate the different pathways for the coal phase-out based on their respective domestic conditions.

However, independent of domestic circumstances, any nation can benefit from developing an efficient and resilient decarbonized energy system. With this goal in mind, the coal phase-out must be complemented by the expansion of renewable generation and power grids and enhanced supply and demand-side flexibility. Sound energy planning and an effective and adaptive policy framework are key to ensuring the success of this process.

3 A consensual vision and strategy for exiting coal is a political and economic signal that provides attractive investment opportunities.

Agreements must be solid as well as flexible to adapt to rapid changes in technology, investment behaviours, and climate policies, including feedback effects.

Sound energy planning and an effective and adaptive policy framework is key to ensuring that low-cost renewables can gradually substitute coal power generation and provide economic, social, and environmental benefits. While a consensual coal phase-out plan is likely to be conservative rather than overly ambitious, it still provides clarity on the future of the energy system and reduces uncertainty. It thereby allows utilities, grid operators, local authorities, employees, and consumers to plan and invest accordingly, in anticipation of a future energy system without coal. Due to this clear direction and vision for the future of the energy system, a solid coal-exit plan tends to accelerate the process.

Moreover, in such an energy transition, the technological, economic, and political environment tends to evolve quickly. Important factors include commodity and renewable technology prices, national and international climate targets, as well as national and international carbon tax and trading regimes. This underscores that a clean energy transition is a process with many moving parts – including the roll-out of necessary grid infrastructure and storage technologies, as well as the electrification of transport, buildings, and industrial heat.

The experience gathered in Germany and Chile to date shows that market developments and policy factors may evolve faster than anticipated by stakeholders, thus requiring preparedness for adaptive responses. At the same time, it is important that countries start planning and implementing their coal exit early to ensure enough time for managing and accommodating such deep and evolving structural change.

While a good roadmap (including clear milestones and goals) is needed to navigate this transition, it is impossible to plan the entire transition from beginning to end. Rather, periodic reviews and updates to the phase-out plan are needed. Thus, if key preconditions for the phase-out are not in place (such as grid expansion or reliable back-up capacity), the closure of individual plants may need to be delayed. At the same time, if the assumptions of the plan prove to be too timid – e.g. if technological advances and cost degression for renewables or storage exceed expectations, or if more ambitious climate goals are adopted, the phase-out plan may be accelerated.

In this process, however, clarity is imperative: above all, there must be a clear commitment that coal is on its way out, as it would be irresponsible to communities and workers, but also economically inefficient, to suggest otherwise. Also, policymakers must spell out clearly who will evaluate the progress made in phasing out coal, based on what criteria, and at what points in time.

4 Investors are ready to embrace the opportunities and business models offered by the decarbonization of energy systems.

As the cost of renewable energy technologies continue to fall, the roll-out of a smart, digitized, decentralized, flexible, and renewable energy system is an attractive economic growth opportunity for investors and nations.

In Chile (and elsewhere), the falling cost of renewables has fuelled an enormous rise in renewable capacity, replacing fossil capacity earlier than what was originally envisaged. While the German coal phase-out has been perceived (and criticized) as excessively costly, this criticism ignores the fact that Germany has not chosen to throw out a perfectly good technology.

Rather, it has been investing to manage the decline of a fossil fuel – and an associated industry – that is quickly becoming obsolete. Indeed, Germany's coal-mining regions, with their unhealthy concentration on a single industry, would invariably require assistance at some point.

Recent developments support this conclusion. Since adopting their respective coal phase-out strategies, both Germany and Chile have observed a faster than expected decline in coal-based electricity generation. In both instances, this has been driven by market forces (in particularly, the comparative price of coal and natural gas), and by declining energy demand due to the COVID-19 pandemic. In Germany, the resurgence of the EU ETS carbon price has contributed markedly to the declining share of coal, including some early retirement of coal capacity ahead of the agreed schedule. As a result, most coal-fired power plants are currently unable to cover their fixed costs.

These economic realities may also help to explain why, in Chile and Germany, utilities were not fundamentally opposed to a coal phase-out. By way of comparison, Germany has placed greater emphasis on compensating utilities for the value of stranded assets – yet in both instances, utilities have (more or less willingly) accepted the reality that the days of coal-based power generation are numbered, and are now embracing an energy future without coal. In Chile, with its high share of relatively young thermal power plants, a particularly relevant question revolves around the conversion of current generation assets. With their connections to transport infrastructure and utility grids, these power plant sites are highly attractive as locations for alternate energy-related uses, including energy storage or green hydrogen production. In this way, the coal phase-out is engendering new opportunities for plant sites, including compelling business solutions for plant owners or for the implementation of just transition strategies. It is worth noting that the conversion of coal-fired power plants to natural gas should not be encouraged; such conversions are questionable from a climate and investment perspective, as natural gas plants will need to be phased out or converted over the midterm. While it is natural that parties with vested interests may fight for the continuation of an unsustainable status quo and thus be reluctant to agree to a coal-exit strategy, these parties may in effect show proactive behaviour once an agreement on coal phase-out has been reached. The earlier such an agreement is reached, the sooner investors, policymakers, and communities can focus on the future and engage in developing the economic opportunities of the energy transition. To be sure, the more time investors, policy makers, and societies have to react to unforeseen opportunities and challenges, the better the outcome for society at large, as well as the affected regions and communities.

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