Chapter 5

Bridging the gap – Phasing out coal

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5.1 Introduction

If the temperature increase is to be kept well below 2°C by 2100, the global economy must undergo rapid decarbonization. The power sector holds a critical role, given the widely available and relatively cheap decarbonization options in the sector (Kriegler *et al.* 2014; Luderer *et al.* 2017; Sachs *et al.* 2014; Williams *et al.* 2012). In most of the scenarios consistent with limiting warming to below 2°C in the Intergovernmental Panel on Climate Change's (IPPC) Fifth Assessment Report (Clarke *et al.* 2014), unabated coal-fired power not equipped with carbon dioxide capture and storage (CCS)[1] declines rapidly, and is almost completely phased out by mid-century[2] (Audoly, Vogt-Schilb, and Guivarch 2014; Kriegler *et al.* 2014; Luderer *et al.* 2017; Rogelj *et al.* 2015; Williams *et al.* 2012) (Chapter 3). In the scenarios consistent with a 1.5°C increase in global mean temperature by 2100, the decline of the power sector's carbon emissions has to be even faster (Rogelj *et al.* 2015), leading to a faster phase-out of power production from coal[3]. The longer the world continues to use coal, the greater the need for negative emissions technologies in the second half of the century (Luderer *et al.* 2013; Riahi *et al.* 2015)[4].

There are currently an estimated 6,683 coal-fired power plants in operation worldwide, with a combined installed capacity of 1,964 GW. Emissions from coal alone were responsible for a major share of past emissions. If run until the end of their lifetime, and not retrofitted with CCS[5], the stock of operating power plants would emit around 190 $GtCO_2$. Furthermore, they would use a large share of the available carbon budget for internationally agreed climate targets figure 5.1 and table 5.1).

Coal-based power generation is the single most important cause of carbon lock-in (Bertram, Johnson, *et al.* 2015; Davis, Caldeira, and Matthews 2010)[6]. Without additional policy interventions, the number of coal-fired power plants would likely continue to increase. In early 2017, across

1 Carbon capture, (transport) and storage (CCS) consists of three stages, beginning with capturing CO_2 from large stationary emitters, such as coal power plants or industrial facilities, then transporting it to an underground storage site, before compressing it in suitable geological formations. Scenarios by the IPCC (2014) projected large-scale CCS utilization, particularly given its potential to provide negative emissions when used in combination with biomass plants (see also Chapter 6).

2 Coal is the most carbon-intensive fossil fuel, responsible for about 46 percent of global carbon emissions from fossil fuels (Olivier *et al.* 2016). It is commonly categorized as steam coal (5,811 Mt; 75 percent market share), metallurgical or coking coal (1,090 Mt; 15 percent market share) and lignite (807 Mt; 10 percent market share), based on its material properties and end use (IEA/OECD 2016). This chapter and most policies focus on steam coal and lignite, which are primarily used for generating electricity.

3 Without large-scale deployment of CCS, achieving climate targets would also involve a large transformation of the upstream coal sector (Meinshausen *et al.* 2009; Bauer *et al.* 2016). Between 82 percent and 88 percent of current coal reserves are considered 'unburnable', compared with 33 percent–35 percent of oil and 49 percent–52 percent of gas reserves (McGlade and Ekins 2015, see also box 5.1).

4 See also Chapter 7 of this report for a detailed discussion.

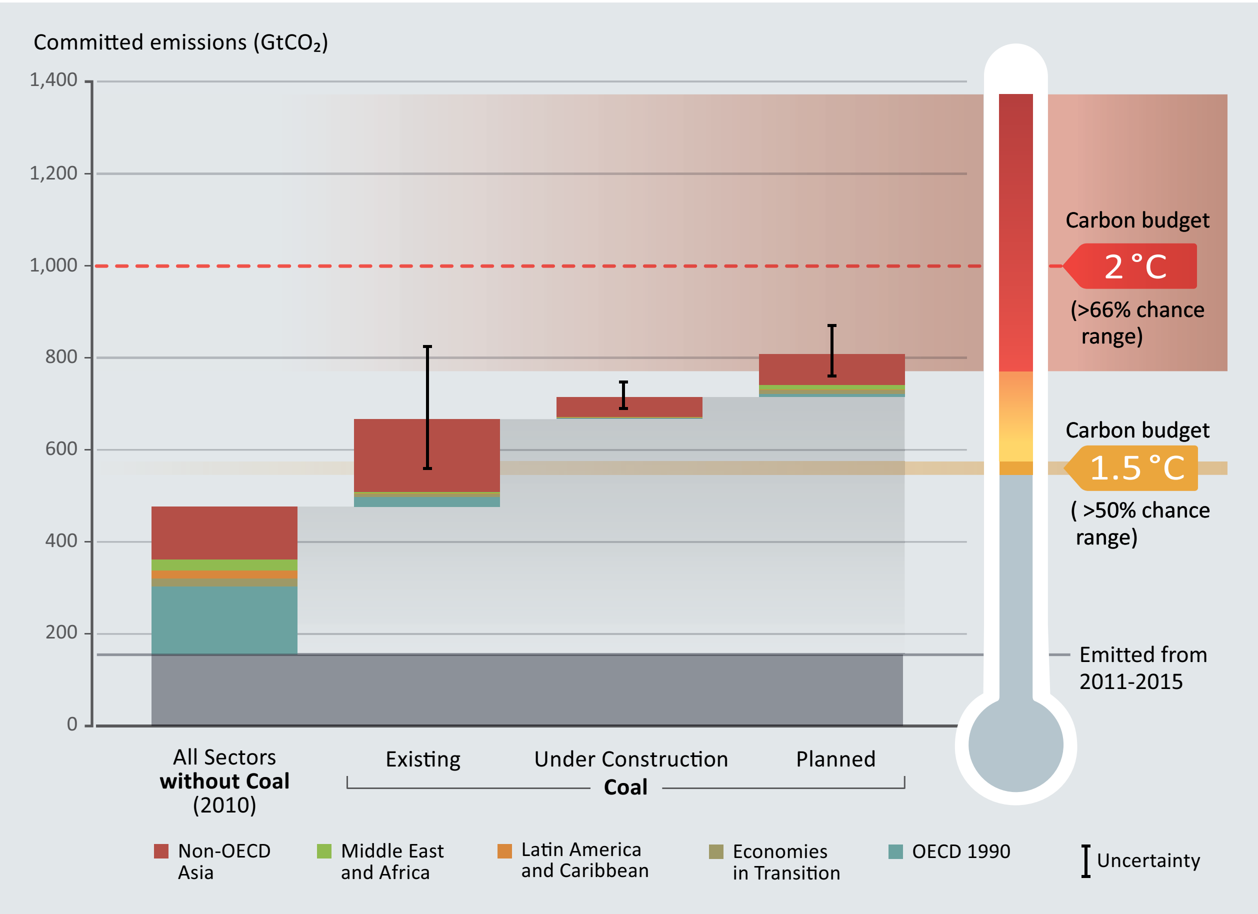
5 Today, there are 17 large-scale CCS projects operating worldwide, mostly in combination with enhanced-oil recovery (EOR), which inject a total of 22 $MtCO_2$/y. Two of the 17 large-scale CCS projects operating worldwide are coal power retrofits: Boundary Dam in Saskatchewan and Petra Nova in Texas. Each of these projects captures and stores >1M tonnes/year, and effectively decarbonizes a unit by 90 percent. The Petra Nova project costs ('all in') are roughly US$100/tonne, with analysts anticipating second and fourth project costs for the same technology at US$80/tonne and US$60/tonne respectively. Although some countries have very little CO_2 storage resources, overall there does not appear to be a shortage of such resources (GCCSI 2017).

6 Coal power plants have a long economic lifetime, often over forty years, meaning that every new coal-fired power commits a large amount of CO_2 emissions if run over its economic lifetime (Davis and Socolow 2014).

the globe there were an additional 273 GW of coal-fired capacity in construction, and 570 GW in pre-construction (Shearer *et al.* 2017). Ten countries make up approximately 85 percent of the entire coal pipeline, with 700 GW being built or planned in China, India, Turkey, Indonesia, Vietnam, Japan, Egypt, Bangladesh, Pakistan and the Republic of Korea alone (Shearer *et al.* 2017). While a large amount of planned power plants were shelved or cancelled in 2016 — particularly in China and India (with reductions of 54 percent and 52 percent, respectively, compared to 2015[7]) — other countries, such as Indonesia, Japan, Egypt, Bangladesh and Pakistan, announced new investments in 2016 (with increases of 40, 60, 784, 40 and 100 percent, respectively, compared to 2015) (Edenhofer *et al.* 2017). If run until the end of their assumed lifetime of 40 years, the plants currently under construction (273 GW) and those planned (570 GW) would lead to emissions of approximately 150 $GtCO_2$, of which 50 $GtCO_2$ can be attributed to those currently under construction (figure 5.1 and table 5.1).

To meet international emissions targets, further lock-ins should be avoided (box 5.1). Nonetheless, this would not suffice, as existing stocks and plants currently under construction would still commit approximately 240 $GtCO_2$ over their lifetime. Closing the emissions gap requires that these plants run with lower capacity rates, and are phased out before the end of their lifetime, and/or retrofitted with CCS facilities.

Figure 5.1: Committed emissions to the atmosphere from coal-fired power plants (existing, under construction and planned) and other economic sectors, by region.



Note:
- Regional breakdowns are consistent with Representative Concentration Pathways, as defined in IPCC (2014).
- Uncertainty ranges indicate differing lifetimes (between 30 years and 50 years), and coal-fired power plants' capacity factors (between 37 percent and 80 percent as per IEA (2016).
- Emission factors are specific to the power plants.
- For the calculation of "all sectors", medium lifetimes of infrastructure are as reported by Davis and Socolow (2014).

Source: Figure based on Edenhofer *et al.* (2017). Data from: Davis and Socolow (2014) and Shearer et al. (2017).

7 The slowdown of China and India is significant because together the two countries accounted for 86 percent of all new capacity between 2006 and 2016. Both countries face a marked slowdown in the anticipated domestic demand for new coal power, due to overcapacity in China and a downturn in solar prices in India (Shearer *et al.* 2017, see also section 5.3).

Table 5.1: Committed carbon dioxide emissions for coal-fired power plants, in $GtCO_2$, by status and region

Scenario	Announced	Pre-permitted	Permitted	Construction	Operating	Total
East Asia	12.19	12.34	6.30	30.41	126.41	187.66
South Asia	6.21	9.87	5.89	8.28	27.42	57.67
South-East Asia	7.00	5.78	2.63	5.21	8.95	29.60
European Union	0.60	0.66	0.17	1.14	7.22	9.79
Non-EU Europe	4.86	5.30	1.70	0.44	3.56	15.87
Middle East and Africa	5.83	1.16	1.94	2.14	2.46	13.52
Latin America	0.61	0.17	0.28	0.37	1.74	3.18
Eurasia	1.65	0.00	0.00	0.20	2.69	4.54
North America	0.00	0.00	0.15	0.00	8.85	9.01
Australia and New Zealand	0.00	0.00	0.00	0.00	1.14	1.14
Total	38.97	35.28	19.08	48.20	190.44	331.97

Note:
- The figures take into account the remaining lifetimes of existing plants.
- A lifetime of 40 years is assumed for newly constructed power plants.
- European Union data refers to the current 28 Member States. North America refers to both Canada and the United States.
- It is assumed that not all permitted, pre-permitted and announced power plants come online.

Source: Edenhofer *et al.* (2017) and Shearer *et al.* (2017).

Phasing out coal can have important societal benefits, going beyond climate change mitigation. Key among these are improved air quality, especially reduced particulate matter and reduced emissions of sulphur dioxide and nitrogen oxides (IEA/OECD 2016 and West *et al.* 2013) (Chapter 6), and increased water availability (Zhou *et al.* 2016). However, a transition away from coal can be expected to be politically difficult (Vogt-Schilb and Hallegatte 2017). Meanwhile, co-benefits and rapidly decreasing costs of alternatives[8] might not suffice to achieve a transformation of the scale, and at the speed, that is required to meet international climate targets. Investment into coal can also be attractive, as it can support other societal goals, such as cheap energy supply, energy security or energy access (Jakob and Steckel 2016). There is also limited evidence that long-term climate targets alone are impacting current investment decisions. Climate policy may not be viewed as credible by fossil fuel investors, for whom returns on continued investment may be assured by (i) lobbying (Dolphin, Pollitt, and Newbery 2016; Kim, Urpelainen, and Yang 2016), (ii) market design, or (iii) limited implementation of domestic policies to meet emission reduction targets (Nemet *et al.* 2017). Without credible additional policies, coal will likely remain attractive in many countries, due to its technological maturity, wide availability and relatively low price (ignoring externalities) (Edenhofer *et al.* 2017; Steckel, Edenhofer, and Jakob 2015).

If climate policies are to be implemented, they will need to be supported to ease the social and economic burden of adjustment (Trebilcock 2014). For example, distributional effects that might result from such policies, be it by increasing energy prices (Sterner 2012) or potential job losses in the industry (Arent *et al.* 2017), can be a major stumbling block for a transition away from coal.

8 In particular, the costs of renewable energy have fallen significantly and faster than previously expected (Creutzig *et al.* 2017). In some places, the costs of renewable energy (on a levelized cost of electricity (LCOE) basis) are now lower than those of their fossil alternatives (depending on geography and available finance).

Box 5.1: Stranded assets

The term 'stranded assets' is used to describe various situations (Caldecott 2017):

- Assets that are lost because of the impact of climate change itself.
- Man-made capital that has to be retired prematurely or is underutilized, because of direct or indirect climate policies (such as coal power plants that become unprofitable after a carbon price is implemented) (Guivarch and Hood 2011; Wynn 2016), or which can simply no longer compete against the falling costs of alternative technologies (BNEF 2017; IEA-RETD 2016).
- Fossil fuel resources that cannot be burned if a given climate target is to be reached, also called 'unburnable carbon' (McGlade and Ekins 2015).

A number of studies have shown that the 2°C target requires early retirement of coal power plants (Guivarch and Hood 2011; Pfeiffer et al. 2016; Rogelj *et al.* 2013), and that the longer ambitious mitigation action is delayed, the more the rate of retirement increases (Bertram, Johnson, *et al.* 2015; Johnson et al. 2015; Luderer *et al.* 2017). Iyer *et al.* (2015) estimate that catching up with 2°C-consistent pathways would involve stranding about 1,500 GW of coal and gas power plants worldwide after 2030, while Johnson et al. (2015) estimate that a carbon price consistent with the 2°C target would strand at least US$165 billion worth of coal plants worldwide.

Furthermore, stringent emission reductions translate into substantial upstream unburnable carbon assets, where the emissions embodied in fossil fuel reserves already exceed extraction budgets consistent with 1.5°C or 2°C (McGlade and Ekins 2015), while OCI (2016) have calculated that developed coal reserves (that is, current mining areas) already exceed the budget for the 1.5°C target. The lower capital intensity of coal (compared to oil and gas) means lower costs of stranding, but does point to both loss of value invested in coal producers (about US$800 billion according to IRENA (2017b), and potential wasted capex in mining (worth US$177 billion) if climate policies are later implemented successfully (Carbon Tracker Initiative 2015). Investor-owned firms hold lower reserves than state-owned companies and nation states, thus state-owned companies and nations may pose a greater risk to exceeding the carbon budget (Heede 2014; Heede and Oreskes 2016), equity considerations notwithstanding (see also section 2.2).

5.2 Incentivizing and managing a smooth transition

Policy instruments will be needed to incentivize the transition, both with respect to avoiding lock-ins, and facilitating the phase-out of existing stocks, including retrofitting them with CCS where feasible[9].

5.2.1 Policy instruments

Global climate policies in general can be organized along different metrics: market-based economic instruments (notably taxes and subsidies, tradable allowances or credits, and border tax adjustments) (Kolstad *et al.* 2014), regulatory non-market-based approaches (such as standards, and non-compliance penalties), and complementary policy instruments (notably government provision of goods and services) (Oei and Mendelevitch 2016). It is increasingly acknowledged that a transition to a low-carbon economy will require adjustment to a variety of fiscal and normative rules that have an impact on investment decisions (OECD 2017). This section assesses possible policy interventions, and how their introduction can be managed in a socially balanced way. Coal phase-out would have different requirements in different geographies for existing coal plants, recently built coal plants, and those in the pipeline. Therefore, a different combination of these instruments might be necessary.

9 Note that application of CCS in the coal sector might result in a prolonged usage of coal and therefore allow for a longer transition period.

Market-based instruments

The economically efficient approach to cutting global coal use (without CCS), as part of an overall drive to reduce carbon emissions, would have governments remove coal subsidies, enforce Pigouvian taxes on local air pollution, and use a carbon price to internalize the global warming impacts of burning coal. A carbon price creates incentives for markets to use all available levers to reduce emissions, and should theoretically result in a broadly cost-effective overall emissions reductions outcome (Cramton *et al.* 2017; Nordhaus 1991; Pearce 1991; Pigou 1920). Pricing carbon strongly disincentivizes the use of coal, as it is the most emissions-intensive fossil fuel.

Many countries have emissions trading and other forms of carbon pricing schemes in place that, in 2016, covered 13 percent of global greenhouse gas emissions (World Bank and Ecofys 2016). However, the resulting carbon prices are typically much lower than the social cost of carbon (the estimated monetized negative impact of climate change caused by greenhouse gas emissions) and lower than the rates required to achieve significant reductions in coal use.

Instead of being taxed, in many countries fossil fuel consumption and production are subsidized, with fiscal subsidies to fossil fuel production and use being estimated to be over US$300 billion, or around 0.4 percent of global gross domestic product in 2015 (Coady *et al.* 2016)[10]. Most of these fiscal subsidies were for oil and gas, with only a relatively small amount for coal. The picture changes dramatically once the lack of taxation of negative externalities of fossil fuel use is accounted for. Comparing actual taxes on coal with the estimated damage to society from air pollution reveals an implicit global subsidy to coal of US$2,400 billion in 2015, or US$3,100 billion (half of total implicit to all fossil fuels) if the damage to climate is accounted for (Coady *et al.* 2016).

In the absence of full implementation of carbon prices, coal taxes could potentially reduce carbon leakage (Collier and Venables 2014), provide credible long-term price signals, and reduce (or even avoid) carbon lock-ins (Lazarus, Erickson, and Tempest 2015). When coordinated among major coal-producing countries, they could raise global coal prices and lower global coal consumption, and hence reduce emissions (Mendelevitch, Richter, and Jotzo 2015).

Non-market-based instruments

Implementing carbon prices that are sufficiently high might not be politically feasible (section 2.2). Hence, complementing a carbon price — or even temporarily substituting it — with alternative policy instruments such as performance standards, feebates, or targeted financial instruments (such as subsidized loans) that apply only to new, clean power plants can avoid early retirement of existing plants, thus preserving vested interests, and ease the phase-out (Bertram, Johnson, *et al.* 2015; Rozenberg, Vogt-Schilb, and Hallegatte 2017). Preventing the construction of new assets is especially vital in countries that currently invest in coal (figure 5.1 and table 5.1). In contrast to a high carbon price, standards, mandates or feebates on new power plants do not prompt current producers to underutilize existing coal plants. While they would avoid stranded assets (box 5.1), they would likely redirect new investments towards greener options. Stated differently, the stock of coal power plants would stop increasing, and instead decrease progressively as plants aged and were retired (Rozenberg, Vogt-Schilb, and Hallegatte 2017).

Another policy option in this direction is to enact a moratorium (a ban) on new coal power plants or coal mines beyond a specific timeline (Bertram *et al.* 2015; Pfeiffer *et al.* 2016; Rozenberg, Vogt-Schilb, and Hallegatte 2017). Those approaches can have advantages in political economy terms, in that they impact owners of existing coal power plants and mines less, and hence reduce resistance to change (Rozenberg, Vogt-Schilb, and Hallegatte 2017). When a high carbon price is not feasible, typically due to political economy considerations, a low price coupled with a moratorium and other complementary policy instruments, such as support for low-carbon electricity generation capacities, could indeed help make progress towards the 2°C target, while drastically limiting stranded assets (Bertram *et al.* 2015).

10 We added together 'pre-tax subsidies' and 'foregone consumption tax revenue' from IMF figures to calculate this total, which we call 'fiscal subsidy'. The IMF adds the failure to internalize externalities related to fuel usage to arrive at its headline 'fossil fuel subsidy' figure.

Complementary instruments

Even if complemented with non-market-based instruments, carbon prices alone would fail to overcome other market failures, notably network externalities or imperfections in the capital market. While usually assumed to play a key role in future electricity supply, renewable energy technologies, such as wind or solar power, require additional infrastructure to provide a reliable electricity supply (IPCC 2014)[11]. To support their increased deployment, governments can invest in improved grid infrastructure and storage facilities to address variable availability (Hirth, Ueckerdt, and Edenhofer, 2015). Smart grids, including bidirectional power flows and metering at the individual level, could further enhance system efficiency, in turn increasing the market share of clean technologies (Iqtiyanillham, Hasanuzzaman, and Hosenuzzaman 2017; Meadowcroft *et al.* 2017; Rifkin 2011).

Being more capital-intensive than coal, low-carbon technologies are sensitive to perceived investor risks, both political and financial, and to other capital market constraints. For example, regional differences in the weighted average costs of capital play a more important role in evaluating investments in renewable energy technologies than differing natural conditions, such as differences in solar irradiation or wind potentials (Ondraczek, Komendantova, and Patt 2015, for photovoltaic technologies). These differences can lead to carbon prices alone being unable to trigger a transition away from coal (Hirth and Steckel 2016).

To address the existing investor risks, and improve the attractiveness of alternatives to new coal investments, instruments for de-risking clean investment are suggested for all financial institutions and governments across the world. These include, for example, support for policy design, identification and removal of regulatory hurdles, improvement of institutional capacity, and provision of bridging investment subsidies. Such financial de-risking instruments can transfer risk from private investors to public actors. A range of 'private sector instruments', such as guarantees, subordinated debt or equity, is already available (Torvanger *et al.* 2016). National or multilateral development banks could employ public financing to mobilize private investments, which contribute to a declared development target. Concessionary climate finance can also be used to de-risk low-carbon investments (Steckel *et al.* 2017), while coal investment could also be made less attractive. In 2016, public finance by G20 countries for coal projects outstripped financing for renewable projects by four to one internationally (Chen 2017).

11 Additional infrastructure investments would also be necessary for increasing the deployment and use of CCS. Recent trends suggest that a large-scale utilization of CCS as decarbonization technology for the electricity sector is unlikely, as the combination of renewables with storage and demand-side technologies provides the cheaper alternative (Breyer *et al.* 2017; Löffler *et al.* 2017). Nevertheless, large-scale power storage technologies to match demand–supply mismatches is still a technological challenge and requires additional research (Annaluru and Garg 2017; Park and Lappas 2017). Critically, the ministers of 26 countries agree that without overt policy support (as has been provided in the past to renewable, nuclear, and power storage technology), CCS will encounter challenges entering the market and achieving emissions reductions.

5.2.2 Managing the transition

Some of the stakeholders negatively impacted by the transition away from coal, including workers, coal owners, and energy users relying on low prices, may have the power to veto proposed reforms (Arent *et al.* 2017; Kern and Rogge 2016; Sovacool *et al.* 2016; Trebilcock 2014). As one example, governments that have tried to pass fossil fuel subsidy reforms on the grounds of technical soundness and administrative feasibility, without taking into account the political economy of reforms, have often failed (Bazilian and Onyeji 2012; Rentschler and Bazilian 2016; Sdralevich, Sab, and Zouhar 2014).

A review of previous experience with reforms in the energy sector provides guidance on measures to navigate the political economy of phasing out coal (Fay *et al.* 2015; Louie and Pearce 2016; Sovacool *et al.* 2016; Vogt-Schilb and Hallegatte 2017)[12]. These include managing the impact on workers, coal owners, industry and energy users, as well as the role of communication.

Managing impacts on workers

A transition away from coal affects many different groups of workers. Historically, transitions away from coal have often left workers and communities to bear the brunt of job losses and deindustrialization (Caldecott, Sartor, and Spencer 2017; Trebilcock 1981). While macroeconomic analyses of the employment impact of switching to more renewable energy usually find net job creation (Cameron and van der Zwaan 2015; Perrier and Quirion 2016; Ragwitz *et al.* 2009; Wei, Patadia, and Kammen 2010), they may mask job losses in other locations, and might hence be a poor indicator for a just transition[13]. Indeed, case-by-case analyses are often needed to assess the kinds of jobs created, their wages and conditions, the skills required by these jobs, and whether they can be accessed by roughly the same population group affected by a coal phase-out (Miller, Richter, and O'Leary 2015).

Support, such as wage subsidies (to encourage hiring in expanding sectors) and unemployment insurance for displaced workers, can help effectively mitigate most of the losses at generally modest costs (Louie and Pearce 2016; Porto 2012). More generally, research on past transitions shows that social dialogue, social protection and economic diversification are instrumental in ensuring just transitions (Caldecott, Sartor, and Spencer 2017; Galgóczi 2014; Healy and Barry 2017). This can be expected to be more challenging in developing countries, where resources and institutional capacities are scarcer and the mining workforce is semi- or unskilled.

Managing impacts on coal owners and industry

A coal phase-out would lead to a devaluation of existing coal assets (section 5.1 and box 5.1). In a situation in which the competitiveness of other industries was reduced, for example following a potential increase in energy prices associated with a coal phase-out process (Branger and Quirion 2014), the prospects of successfully completing a coal phase-out process would be compromised[14]. Model analyses find that losses incurred by coal owners could be compensated by governments redistributing a fraction of the carbon rent[15] (Arent *et al.* 2017; Bauer *et al.* 2016; Goulder and Schein 2013; Kalkuhl and Brecha 2013). Several countries or regions, such as Alberta in Canada, have coal phase-out agreements, to ensure an efficient, progressive, and politically acceptable reduction in coal power generation (Jordaan *et al.* 2017)[16]. In the United Kingdom, compensatory subsidies were given to support the industry in its efforts to compete in the reformed electricity market (Oosterhuis and Brink 2014).

Managing impacts on energy users

The negative impacts of a coal phase-out on poor and middle-class energy users, notably through increased electricity prices, can also challenge the political feasibility of reforms, regardless of the progressivity or regressivity of increased coal prices on consumers (Lindebjerg, Peng, and Yeboah 2015; Arze del Granado, Coady, and Gillingham 2012)). Compensatory redistributive policies can mitigate the distributional impacts to a large extent, especially if a fraction of revenues is recycled into transfers to poor and middle-class households (Brenner, Riddle, and Boyce 2007; Burtraw, Sweeney, and Walls 2009; Callan *et al.* 2009; Coady, Parry, and Shang 2017; Gonzalez 2012; Liang and Wei 2012; Rausch, Metcalf, and Reilly 2011; Symons, Proops, and Gay 1994). This can be done through different instruments that specifically target the subset of the population that is directly affected. For example, direct cash transfers can be used as compensatory measures, where appropriate systems exist (Rentschler 2015; Robles, Rubio, and Stampini 2015; World Bank 2015). Alternatively, compensation can be offered through in-kind measures, such as electrification in poor and rural areas, distributing efficient light-bulbs, improving public transport, or eliminating fees at government-run schools (Coady, Parry, and Shang 2017; Fay *et al.* 2015; Garg *et al.* 2017).

Redirecting resources, from coal use to the provision of public goods, helps governments garner support for coal phase-out plans (Stiglitz and Stern 2017). For instance, governments can use revenues from taxation or savings from avoided fossil fuel subsidies to invest in public infrastructure (Jakob *et al.* 2016, 2015), energy infrastructure[17], or social assistance (Hallegatte *et al.* 2016). Governments can also

12 Including energy taxation, energy subsidy removal, and carbon taxes, as well as adjustment packages for, and re-training of, energy sector workers.

13 The International Labour Organization has has produced the Guidelines for a Just Transition Towards Environmentally Sustainable Economies and Societies for All (International Labour Organization 2015), which are explicitly recognized in the Paris Agreement (United Nations 2015).

14 These kinds of dislocations played a role in the 2016 US elections, where loss of coal jobs over the past 20–30 years affected entire communities and states, leading to massive shifts in voting behaviour.

15 The 'carbon rent' describes the economic value of being allowed to emit, which would be captured by governments implementing a carbon price, that is a tax or an emissions trading scheme.

16 To do so, the government of Alberta committed to "provide transition payments to the companies which were originally slated to operate their coal-fired units beyond 2030". These payments "represent the approximate economic disruption to their capital investments" (Government of Alberta 2015).

17 See, for example, the case study on India, in Section 5.3.

use those savings to reduce income taxes and payroll taxes, to correct impacts on those consumers who do pay taxes (Metcalf 1999).

Cash transfers (to directly affected communities) and tax reductions (benefiting all citizens) are not necessarily mutually exclusive (Parry and Williams 2010). Indeed, a combination of transfers and a reduction of distortive taxes funded by energy taxes could foster more progressive income distribution patterns, and drive a reduction in low-cost coal usage (Bach *et al.* 2002).

Communicating policy packages

Communicating potential benefits and involving stakeholders is an essential precondition for a successful transition away from coal (Healy and Barry 2017). Coady *et al.* (2017), comparing 32 energy pricing reforms, found that the absence of an effective communication strategy was decisive in unsuccessful past reforms.

5.3 Country studies

This section presents policies, measures and instruments being used by major coal users and producers around the world, to highlight the challenges and opportunities associated with coal phase-out. Success rates differ and major gaps need to be bridged for a quicker phase-out. However, the breadth of positive experiences is enough to offer a buoyant outlook on the overall direction.

5.3.1. Australia: coal exports and policy challenges

In Australia, which has relied heavily on its abundant coal reserves for domestic electricity production, transitioning away from coal is likely to pose significant policy challenges. It is widely anticipated that the number of coal-fired power plants will continue to decline, as plants come towards the end of their planned lifetimes. A number of older coal-fired power plants have been shut down, and new coal-fired capacity is now widely seen as 'uninvestable' by the private sector, due to carbon risks and because renewable energy is rapidly gaining a cost advantage (Morgan 2017).

Being the world's second largest coal exporter[18], the even bigger question is the future of coal exports. Thermal coal exports, which are directly dependent on other countries' climate change policies, currently stand at around 200 million tonnes per year (Australian Government 2017), almost double the volume from a decade ago. Large-scale expansion of coal mining for export from inland areas of north-eastern Australia is under discussion.

There is currently no policy to accelerate the phase-out of coal in domestic use, and no systematic framework to ease the transition away from coal in regions where large coal-based infrastructure exists, or where coal is mined. Australia's experience with climate policy has been a difficult one, with the issue heavily politicized, and emission reduction policy instruments the subject of political contest. Australia is the only country that introduced a full-scale carbon pricing scheme (in 2012) and then abolished it (in 2014). Policy uncertainty is deep-seated in the energy sector, stifling investment (Jotzo, Jordan, and Fabian 2012).

5.3.2 China: slowly turning the wheel

Being the world's largest consumer of coal (BP, 2017), and relying largely on coal in its energy supply, China has (in its Nationally Determined Contribution) committed to achieve a peak in coal emissions by 2030, and eventually diversify its energy supply. Since 2013, coal consumption seems to have stalled, with some claiming that the period of major growth in China's coal consumption is already over (IEA 2016) or that China's coal consumption has already peaked (Green and Stern 2017; IEA 2016).

While it is too early to interpret current developments, China is adopting a wide range of cross-sectoral policies and measures to reduce its coal production and consumption, largely motivated by the need to tackle local air pollution (Chong *et al.* 2015; Hao *et al.* 2016). Specific policies include phasing out coal in key cities and regions to improve air quality, improving the efficiency of coal-fired power plants and industrial boilers and furnaces, mandatory closure of old and inefficient coal mines, as well as coal-fired power plants, and industrial facilities. For instance, during the 2011–2014 period, 24 GW of coal-fired power plants and 473 million tonnes of coal production capacity were closed (Hart, Bassett, and Johnson 2017; NDRC 2016). The Government also promotes the development of low-carbon energy sources, for example by feed-in tariffs for renewable energy and granted grid access. The newly introduced carbon dioxide emissions trading scheme can also be expected to make coal consumption relatively unattractive (Swartz 2016). In addition, to address the overcapacity of industries and power generation, the Government has also halted the approval of new capacity[19], although it remains to be seen how many of these projects will be cancelled or just postponed until after 2020. To soften the social side effects of closing insolvent, polluting and inefficient state-owned coal mines, an Industry Adjustment Fund has provided Chinese Yuan100 billion (approximately US$15 billion) to manage unemployment in the steel and coal sectors (NDRC 2016).

Despite those developments, China still added 14 GW of new coal-fired power generation capacity during the first half of 2017. Even though this increase is 52 percent smaller than that during the same period in 2016 (CEC 2017), at the beginning of 2017 there were still 280 GW in the pipeline, of which 145 GW were under construction (Shearer *et al.* 2017). Facing a marked slowdown in new coal capacity in the country, the central government has encouraged Chinese coal enterprises to seek opportunities outside the country (Bal Kishan Sharma 2016). In recent years, China has become a major player in developing coal-fired power plants abroad, including providing the funding, equipment and labour. By the end of 2016, China had been involved in the construction of a total capacity of 250 GW of coal-fired

18 Note that Australia is the largest exporter of coal when also accounting for metallurgical coal.

19 In the second half of 2016, 120 GW acronym of power plant capacity under construction and planned were halted (Zhang 2017).

capacity at different stages (that is, from the planning phase to plants that were operational in 2016) across the globe (Ren, Liu, and Zhang 2017).

5.3.3. Europe: Learning from past experiences

In terms of managing a coal phase-out, trends in European countries are diverging, roughly along an east/west divide. Most Western European countries have either already phased out coal (Belgium, Cyprus, Luxembourg, Malta, and the Baltic countries), agreed on a phase-out path within the next 10 years (Portugal, Finland, the United Kingdom, Denmark and Austria), or are currently discussing pathways with declining coal demand in the medium term (Germany, France, Spain, Italy and the Netherlands) (Graichen, Kleiner, and Buck 2016). Lessons from these experiences can be drawn to design future coal phase-out pathways. The closure of most steam coal mines in Western Europe (located mainly in the United Kingdom and Germany) at the end of the 20th century was based on economic reasoning. Public subsidies were granted with the aim of securing supply and easing the social impact of reduced coal production (Fothergill 2017; Galgóczi 2014; Matthes *et al.* 2015). Local supplies were at first replaced by steam coal imports, and eventually also by natural gas. The latter was supported by European Union policies, in combination with national measures such as the introduction of a carbon dioxide price floor and emission performance standards in the United Kingdom (Fothergill 2017; Matthes *et al.* 2015).

Public financial support in Western Europe has been shifting from conventional technologies such as coal (or nuclear) towards renewables. Energy transitions, as seen in countries such as Denmark (Danish Energy Agency 2017; Gerdes 2016) and Germany (Matthes 2017; Renn and Marshall 2016), have been facilitated by cooperation between unions, employers, governments and research institutions, in a continuous process spanning several decades (Sovacool 2017).

In Eastern Europe, countries (most notably Poland) continue to support coal-fired electricity with the aim of backing up their domestic coal production. Energy security and energy prices are major political concerns, while European Union climate policy and the German "transition towards sustainable energy" are regarded rather critically across political parties (Bouzarovski and Tirado Herrero 2017; Marcinkiewicz and Tosun 2015; Szulecki *et al.* 2016). As a consequence, coal mining companies, under economic pressure due to the plummeted global coal prices, are given (indirect) state subsidies or are renationalized (Jonek Kowalska 2015; Widera, Kasztelewicz, and Ptak 2016). Debates on potential coal phase-out scenarios are met with great scepticism, due to previous negative experiences with (coal sector) restructuring programmes having resulted in high unemployment, as they failed to create jobs in other sectors (Suwala 2010; Szpor 2017). However, missing the opportunity to start the necessary structured phase-out process might result in difficulties to transform the industry in a socially balanced way, risking much bigger complications in the future for the regions involved. In turn, in some countries, ongoing lock-ins and related unwillingness to address a transformation might also negatively impact future approaches to European Union climate policy (Marcinkiewicz and Tosun 2015).

5.3.4. India: balancing multiple objectives

India's starting point is the urgent need for poverty alleviation and more energy for development: in 2016, 21.9 percent of Indians lived below the national poverty line, while more than 240 million people lacked access to electricity (ADB 2017; IEA 2016). The country, in line with many others, faces a dilemma in addressing its developmental goals: it needs to respond to demands in poverty reduction, energy access and urbanization, while reconstructing its development pathway towards a cleaner energy system that has been coupled historically with fossil fuel use (Arent *et al.* 2017).

Coal has remained the mainstay of India's electricity generation, contributing 61 percent of total national generation capacity (Central Electricity Authority Government of India 2016). With the goal of providing power more efficiently to more people, India is investing in modernizing its power plant fleet. Since 2006 the country has added 151 GW of new coal power, making a total of 218 GW as of June 2017, with about 75 percent of this capacity being subcritical (Shearer *et al.* 2017). Coal-based power plants closed or declared non-functional due to their inefficiency and pollution amounted to 18.5 GW in 2013–2014, 23 GW in 2014–2015, 26.8 GW in 2015–2016, and 30.5 GW in 2016–2017) (Ministry of Power, Government of India, n.d.). There are plans to shut down about 37 GW of antiquated, heavily polluting subcritical coal plants in the near future (Singh 2016).

Coal use in India is subject to a form of carbon tax. Total collections of around US$ 9 billion until June 2017 are mainly used to support renewable energy programmes. India plans to install 175 GW of renewable power by 2030, which includes 100 GW of solar photovoltaic power (GoI 2015). 4 GW of solar-powered capacity was added to the grid in 2016, that is double the addition of the previous year (IEA 2017).

Energy security concerns are often presented as a major barrier for India to quickly and decisively turn away from domestic coal (Garg and Shukla 2009). In addition, coal production, transport and usage and ash disposal employ almost one million people[20]. Income from coal royalties constitutes almost 50 percent of total earning of states such as Chhatisgarh, Jharkhand and Odisha (Mondal 2017), which are some of the least developed large Indian states. Therefore, and perhaps more so than in other countries, coal use policies have strong socio-economic and sociopolitical linkages. A successful energy transition in India hence requires a broader perspective that includes economic development and measures that balance the associated social transformation, notably protecting displaced workers (Khosla *et al.* 2015; Reddy 2016).

20 Coal mining is the second largest employer in India (the largest is the railroads, which ship coal as their number one product and revenue source).

5.3.5. Indonesia: covering increasing demand with domestic resources

In 2015, Indonesia was the world's fifth largest coal producer and the largest steam coal exporter in the world, exporting mainly to neighbouring countries, such as China, India, Japan, the Republic of Korea, and the Philippines (IEA/OECD 2016). In the last two decades, coal production has accelerated sharply, but the most recent years have seen a decrease in both production and exports, particularly to China and Japan. Coal contributes to 2.4 percent of Indonesia's gross domestic product (GDP), and in 2014 led to US$22 billion in exports (PWC Indonesia and ICMA 2016).

With Indonesia increasingly using its coal for domestic purposes, it is now also the world's eighth largest coal consumer. About 27 GW of coal capacity provide more than half of the electricity generated in the country (MEMR 2016). Existing power plants are comparably inefficient and have low environmental standards, leading to high emissions of nitrogen oxides, sulphur dioxide, and particulate matter (Centre for Science and Environment 2017).

Indonesia's electricity demand is expected to increase rapidly, as millions will gain access to electricity (Enerdata 2015). The country aims to provide an increasing share of energy by domestic sources, including coal, although due to lower-than-expected economic growth rates, 7 GW of planned coal-fired power plants were recently deferred in Sumatra and Java. The state-owned utility (PLN) nevertheless estimates that, in the next decade, 77 GW of additional capacity will be needed, of which 32 GW are planned to be covered by coal plants (MEMR 2017). Building those would cause coal use for electricity generation to triple by 2025. To secure domestic supply, the country has announced in its National Energy Plan that it will regulate exports.

Indonesia is also rich in other energy sources. The country is a large producer and exporter of natural gas, and has large potential for renewable energy, not only in solar, wind and biomass, but also hydropower and geothermal power, the latter of which could, in some cases, produce power at a relatively low cost (IRENA 2017a). There are plans for exploration and possible significant expansion of hydropower and geothermal power, but implementation tends to face significant practical hurdles.

5.3.6. South Africa: political lock-in

The lock-in of interests, institutions, and infrastructure may slow down the process of coal phase-out in South Africa, despite economics favouring low-carbon alternatives. South Africa is a good example of how the politics of a country may make incentivizing a transition away from coal substantially more difficult. The country depends on coal for the production of 90 percent of its electricity, in a sector dominated by the state-owned, vertically integrated monopoly Eskom (Eskom 2017).

In scenarios compatible with the 2°C target, coal-fired electricity is phased out before 2050 (Burton *et al.* 2016). Nonetheless, independent power producers are planning, and Eskom is building, new coal-fired capacity at costs that are approximately 40–50 percent higher than the prices achieved for wind and solar photovoltaic in recent renewable energy auctions (CSIR 2016). Independent power producers will receive 30-year power purchase agreements and guaranteed minimum off-take (Baker and Burton, in press). A regulated electricity price, state subsidies, and guarantees on Eskom's debt have offset the large cost and time overruns at plants under construction. Stated differently, although new coal-fired capacity is no longer competitive, as the state-owned monopoly Eskom is not subject to competitive electricity markets, investors in new coal plants are essentially guaranteed returns on their investments through the institutional arrangements in the electricity sector. Furthermore, the grid operator Eskom is able to limit a rapid transition, as it compares long-term prices for new capacity against the fuel costs of depreciated coal plants, without a clear differentiation in the market between overall system efficiency and Eskom's financial interests.

5.3.7. United States of America: cheap alternatives

A dramatic reduction in coal use by United States power utilities was facilitated by several factors. First and foremost was the availability of abundant low-cost natural gas, and some expectation that costs would remain low indefinitely. Two major studies (DoE 2017b; Houser, Bordoff, and Marsters 2017) support this view, stating that low-cost gas drove the majority of coal-to-gas fuel changes. Additional factors included conventional pollution controls (such as regulations to reduce mercury emissions), concern over carbon liability (notably through the Clean Power Plan, but also through shareholder votes), and the age of many shuttered plants (some over 60 years old). This suggests that access to sustained low-cost gas can accelerate a coal-to-gas transition. Similarly, in regions where gas is scarce or expensive, that transition would be slower (Citi GPS 2015). It should be noted that further closures will continue, but will likely plateau as the oldest, dirtiest, and least efficient plants close.

Recently, a number of policy proposals have emerged to incentivize the deployment of CCS. One of the more promising approaches concerns a production tax credit for CCS, which pays operators for tonnes stored or used (the FUTURE Act (US Senate 2017)). By guaranteeing a fully refundable tax credit for 12 years of US$50 for saline formation and US$30 for carbon dioxide use (including Enhanced Oil Recovery), its goal is to create markets for CCS technology and projects such that project financing is possible. Additional proposed policies include a combination of production and investment tax credits (White House 2016, 2015), changing renewable portfolio standards to clean energy portfolio standards (Great Plains Institute 2016), building CCS pipeline infrastructure (DoE 2017a), providing access to master limited partnerships (Coons 2015), and tax-exempt debt financing (Portman 2017).

5.4. Synthesis and policy discussions

Phasing out coal consumption in the power sector (without CCS) is an indispensable condition for achieving international climate change targets, but one that is at odds with recent developments. At the global scale, the stock of coal-fired power plants is increasing, as are emissions related to coal. The existing stocks, in combination with what is currently planned and built (assuming standard lifetimes and usage rates), will account for a significant share of the available carbon budget for a 2°C target, and would make a 1.5°C target probably infeasible. Avoiding further lock-ins is therefore a major and urgent requirement, as is phasing out existing coal use gradually.

Coal is mainly used in the power sector, where cleaner and mature technological alternatives are available at increasingly lower costs. However, the low price (ignoring externalities) of coal, wide domestic availability, and path dependencies under a business-as-usual scenario could make coal an ongoing large investment. Its negative externalities, such as air pollution, land degradation and airborne emissions, are regularly not priced in, leading to economic incentive structures that favour the extraction and use of coal over clean alternatives. Particularly where energy demand is increasing rapidly, investments in coal are still attractive. While case studies suggest that new coal plants are being considered increasingly risky and new investment growth is slowing down, stronger policy interventions are needed to turn the tide.

With regard to a transition away from coal, it is hence pivotal to price in the negative side effects of coal through appropriate mechanisms. Increasing prices would affect the current stock as well as future investments, by making current plants as well as future investments less attractive than other alternatives. Subsidies for coal, where they apply, should be phased out immediately. On the other hand, a carbon price, or pricing coal directly (for example in coal-producing countries) needs to be phased in very soon. This would generate revenues that in turn could help ease the transition, for example by financing public infrastructure, social security systems or investments in clean energy infrastructure.

Even though getting the prices right is highly important, a transformation will likely need to be backed by a set of complementary policy instruments. Their implementation can be expected to be politically challenging. Even though they increase global welfare, policies necessary to phase out coal will negatively affect a society's important interest groups; not only producers and owners of coal, but also workers that are employed in the industry, and households or energy-intensive industry that benefit from current low energy prices. These groups might have the power to veto measures necessary to trigger the transformation. Therefore, for a transformation to be successful, their interests need to be taken into account and addressed by additional measures, be it compensation for higher prices or lost business models, training for workers or the provision of alternative employment options. Examples for successful transformations include introducing phase-out agreements between important stakeholders in a country, phasing out inefficient plants first, reducing coal subsidies and promoting renewable energy.

Scenarios that achieve temperature stabilization well below 2°C do not envisage any further room for new investments into coal. Given the difficulty of retiring or phasing out coal once plants are built, it is even more important to ensure that no new coal-fired power plants are constructed, and that carbon lock-in from coal is reduced to a minimum. Financial institutions worldwide should realize that financing coal is quickly becoming riskier, as these investments would become stranded. Energy investments are, however, required to tackle energy poverty in many developing countries, and to upgrade energy infrastructure even in many developed countries, which will need to move towards alternatives. Countries should ensure that alternatives can enter the market easily. This requires investments in the smart grid infrastructure and storage capacities that facilitate the integration of variable, low-carbon alternatives. Additionally, investments in alternatives to coal (such as renewable sources of energy) should be supported, for example by de-risking investments for investors.

Considering the very recent developments of the coal pipeline (that is, power plants that are planned or under construction) gives some reason for hope. The pipeline decreased significantly in 2016 (compared with 2015) and many power plants that were planned have been shelved or even cancelled. Important emerging economies that are largely dependent on coal, such as China and India, have announced policies that address coal consumption from various angles, including price mechanisms and policies that can socially support a transformation.

However, despite the coal pipeline shrinking, there are still large investments in new coal capacities. Some countries have recently announced that they will invest more heavily in coal (often alongside large investments in renewable energy), primarily to cover their increasing energy demands. A transition away from coal will only be successful if poor, fast-growing countries seek low-carbon alternatives to cover their rapidly increasing energy demand. Making those alternatives viable will require strong policies around the globe. Developing and newly industrializing countries will likely need support from the international community to design and implement the policies that are needed to achieve multiple societal objectives, including energy provision and achieving climate change mitigation targets.