# When is a carbon price floor desirable?

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## David M. Newbery, David M. Reiner, Robert A. Ritz

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## Abstract

The EU carbon price lies well below estimates of the social cost of carbon and "target-consistent" carbon prices needed to deliver ambitious targets such as the 40% reduction target for 2030. In light of this, the UK introduced a carbon price floor (CPF) for its electricity sector in 2013 and the new Dutch Government has recently made a similar commitment, while successive French Governments have called for an EU-wide CPF. This paper analyzes the impacts and design of a power-sector CPF, both at the EU and national level, using a political-economy approach. We find a good case for introducing such a price-based instrument into the EU ETS. We suggest that a CPF should be designed to "top up" the EUA price to €25–30/tCO$_2$, rising annually at 3–5% above inflation, at least until 2030. We argue that the new EU Market Stability Reserve enhances the value of a CPF in terms of delivering climate benefits, and discuss the potential for a regional CPF in North-West Europe. We also review international experience with price floors (and ceilings).

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## 1. Introduction and policy context

Stern (2007) argued that greenhouse gas (GHG) emissions give rise to “the greatest market failure the world has ever seen”. Following the 2015 *Paris Agreement*, countries around the world have announced indicative plans towards meeting the goal of net-zero emissions by the second half of the century. The European Union “Energy Roadmap 2050” aims to reduce carbon emissions by 80-95% by 2050 (relative to 1990 levels) and it has enacted a 40% reduction target for 2030, with the electricity sector decarbonizing earlier and more strongly than other sectors. The pricing of carbon emissions is the primary economic instrument to address the market failure associated with the (unpriced) external effects of climate damages.[1] Today, an increasing number of jurisdictions are implementing carbon pricing as a cornerstone of climate policy, at the national and sub-national levels (World Bank, 2017).

The EU has taken a global leadership role in carbon pricing, beginning with the introduction of its Emissions Trading Scheme (ETS) in 2005. The EU ETS has, however, so far failed to deliver the carbon price signal that is widely seen as necessary to incentivize the low-carbon transition. Its carbon price has mostly fluctuated within a band of €5–10/$tCO_2$ since the early 2010s, well below estimates both of the social cost of carbon (SCC) and of “target-consistent” carbon prices. Moreover, as there is virtually no forward-trading liquidity beyond a three-year horizon, longer-run carbon prices remain a “missing market” problem. Reforms to the EU ETS have been complicated by its political economy, notably achieving unanimity across EU Member States. The Market Stability Reserve (MSR), due to begin operation in 2019, increases complexity and may still not ensure a sufficiently strong carbon price signal.[2] In short, policy failure sits alongside market failure.

Against this backdrop, the idea of a carbon price floor (CPF) is gaining prominence in the policy debate. Since April 2013, electricity generation in Great Britain has been subject to a CPF “to support and provide certainty for low-carbon investment” (House of Commons, 2018). It is structured as a “top up” to the EU ETS, with a Carbon Price Support for 2018-19 of £18/$tCO_2$. In October 2017, the new Dutch government announced a similar plan to introduce a *national* CPF. By contrast, President Macron of France has recently advocated an *EU-wide* CPF. This policy debate sits alongside the *proximate* objective of closing (unabated) coal-fired power generation, which has emerged in several European countries.

In this paper, we analyse the desirability of both of these CPFs. Given its central role for early decarbonization and recent policy attention, our analysis focuses on the electricity sector; in doing so, we sidestep issues of international competitiveness that arise for industries with significant non-EU trade. We take a political-economy approach that incorporates both market failures and policy failures in current EU climate policy.[3]

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[1] The basic economic argument for a market-based policy, such as a cap-and-trade scheme or a carbon tax, is that it delivers current emissions reduction at least cost to society by inducing the marginal cost of abatement to be equalized across regulated entities. It thus exploits the gains from trade between entities that can cheaply cut emissions and others.

[2] Following agreement on an EU ETS reform package in November 2017, the EU carbon price has risen to around €15/$tCO_2$ (as of May 2018). We discuss these reforms in greater detail in Section 2.

[3] While our focus is on the EU, our analysis also offers insight to other jurisdictions seeking to implement well-functioning carbon markets to deliver on climate targets. Many of our arguments also apply to the electricity industry outside Europe.

Our main arguments, which we discuss below in more detail, are as follows. First, there is a good economic case for the introduction of price-based element into the quantity-led EU ETS, thus making it a "hybrid" instrument. A CPF is an attractive practical way to introduce such a hybrid—which is more efficient than a pure ETS or a carbon tax alone.

Second, an EU-wide CPF can help fill the "missing market" gap of longer-term carbon prices and bring forward low-carbon investment by guaranteeing a minimum return to emissions reductions. This CPF a "low regret" policy: it directly addresses the risk of a "too low" carbon price in the absence of stronger EU ETS reform—and it can reassure investors whether or not other reforms gain pace.

Third, a well-designed national CPF can play a similar role but comes with greater intra-EU trade distortions. Member States seeking to stake out climate leadership by adopting stringent domestic emissions targets may nonetheless find a national CPF attractive because it is easier to implement than an EU CPF. To enhance its durability, such a national CPF may need to be accompanied by an emissions performance standard (EPS). We also discuss the potential for a policy dynamic leading to a regional CPF beginning in North-West Europe.

We suggest that a power sector CPF should be designed as a carbon levy to "top up" the EUA price to €25–30/t$CO_2$, rising at 3–5% annually above the rate of inflation, at least until 2030. This would yield significant coal-to-gas switching, is more practical than relying on contested estimates of the SCC and in line with target-consistent carbon prices. We also argue that the new MSR, which is expected to begin cancelling surplus EUAs from 2023, enhances the medium-term value of such a CPF in terms of delivering climate benefits.

This paper contributes to the academic literature in four principal ways. First, we discuss the rationale for and design of a carbon price floor in a world characterized by *multiple* market failures; by contrast, most prior research focuses solely on the narrow case of a *single* market failure (in form of the climate externality). Second, and related, we combine standard economics with analysis of the underlying *political* economy of carbon pricing, including the possibility of policy failure (notably in the design of the EU ETS). Third, we update earlier literature in light of recent policy developments in EU carbon pricing; most existing academic contributions on a carbon price floor date back to the early 2010s or before. Fourth, we focus specifically on the power sector.[4]

Finally, we must acknowledge that our analysis is necessarily based on simplifying assumptions. We analyze a CPF as a "sub-global" climate policy carried out by the EU (or parts of it), without addressing global coordination with jurisdictions outside the EU. Thereby we implicitly work on the premise that significant (unilateral) climate action by the EU is itself desirable, given that this is in line with stated European climate-policy commitments.

The paper is structured as follows. Section 2 discusses recent EU ETS reforms and reviews international experience with carbon price floors (and ceilings). Section 3 presents the case for a hybrid ETS design and our political-economy analysis of an EU and national CPF. Section 4 discusses broader interactions between a CPF and other climate-related policies. Section 5 concludes.

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[4] Key earlier policy papers on CPFs (and price ceilings) include Jacoby and Ellerman (2004), Burtraw, Palmer and Kahn (2010), and Wood and Jotzo (2011); we further discuss the literature in the first part of Section 3. The recent report by the Carbon Pricing Leadership Coalition (2017) provides a comprehensive discussion of carbon pricing but does not analyze the use of CPFs.

## 2. EU ETS reform and international policy experience with carbon price floors

In this section, we summarize the challenges of EU ETS reform, then describe in detail the British carbon price floor (CPF) and its impacts, and finally present an overview of broader international policy experience towards CPFs and related measures.

### 2.1. EU ETS reform

Securing the unanimous agreement of 28 countries to change a system that, via its low carbon price, clearly benefits some coal-intensive electricity systems has proven difficult because such countries have an effective veto over potential reforms. Faced with low EUA prices, the EU has engaged in a series of efforts to reform the EU ETS, leading to multiple iterations involving the European Commission, European Council and European Parliament. The Council set out principles for ETS reform in October 2014, followed by the Commission offering a proposed Directive in July 2015. The Parliament and Council laid out their respective positions in February 2017, which led to six rounds of trilogue during 2017.

The main debates have been over the rate at which the total volume of emissions will be reduced (the so-called linear reduction factor, LRF), the number of allowances set aside in a market stability reserve (MSR), a new mechanism to 'limit the validity of allowances in the MSR' from 2023 onward, and the need for regular review (European Council, 2017). Agreement was finally reached between the Council and Parliament in November 2017 and ratified by the Parliament in January 2018. Since these announcements, the EUA price has risen from around €6/$tCO_2$ during much of 2017 to around €15/$tCO_2$ (as of May 2018). A major focus of these reforms has been to deal with the accumulation of billions of EUAs; this stood at 2 billion after Phase 3 and rose to 2.1 billion in 2013, before falling back slightly to 1.7 billion by the end of 2016.

The MSR, originally agreed in 2015, was finally established in January 2018, and begins operations from January 2019. As long as the EUA surplus remains above 833 million, 24% of the surplus will be removed each year between 2019 and 2023 and placed into the reserve, before dropping back to 12% per year until 2030. Moreover, from 2023, if the MSR volume exceeds the EUA volume auctioned in the previous year, this excess will be 'invalidated' or removed from the MSR. This cancellation mechanism is expected to remove a large number of EUAs, with estimates of ranging between 1.7–2.4 $GtCO_2$ over the course of Phase 4 (Perino and Willner, 2017; Thomson Reuters, 2017).

While the recent EU ETS reforms, and specifically the prospect of cancelling surplus EUAs in the MSR, are likely an improvement over its prior design, concerns remain. First, the MSR as it is currently conceived will have no long-run effect on the emissions cap beyond Phase 4. Second, by linking medium-term EUA supply to market conditions in a highly non-linear and time-varying fashion, the MSR rules are opaque and overly complex.[5] Third, large uncertainty around the future EUA price remains, notably the risk of it being "too low" to deliver sufficient low-carbon investment. Indeed, analyst estimates of future EUA prices vary

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[5] Perino (2018) writes: "… the rules should be simple and stable and their impacts predictable such that both market participants and regulators can understand them readily and respond accordingly. Such mechanisms do exist — but the new rules for Phase 4 are not among them."

widely, with a range from €10/$tCO_2$ to €36/$tCO_2$ by the end of 2030 and an average 2025 forecast of €20.75/$tCO_2$ (see *Carbon Pulse*, 12 April 2018). Low future EUA prices are consistent with high rates of discount, which reflect enduring uncertainty and lack of credibility of the ETS (Schopp and Neuhoff, 2013).

The literature to date has similarly been sceptical about the MSR approach. Salant (2016) argues against such *ex post* interventions in ETS design. Perino and Willner (2016) do not find clear evidence that the MSR will provide sufficient incentives to invest in low-carbon technologies where "projects with long lead and life times might be negatively affected"; the simulation results of Perino and Willner (2017) suggest that the MSR has only a very limited impact on EUA prices up to 2037, even under an increased allowance intake. The only formal impact assessment of the MSR dates back to 2015 (EC, 2015), and does not incorporate central features of the stronger-than-expected 2017 agreement on MSR design.

### 2.2. The case of the British carbon price floor

Britain paved the way in demonstrating the potential of a CPF to help address the failures of the EU ETS in the power sector. The idea of a national CPF first emerged in the UK's Coalition Agreement following the 2010 election.[6] After a public consultation, the CPF was introduced in the 2011 Budget (HM Treasury, 2011a) to come into effect on 1 April 2013. One reason underlying the UK's CPF was the binding obligation imposed by the *Climate Change Act 2008*, requiring Government to demonstrate progress in decarbonising the economy. The GB electricity sector, in which a fuel switch from coal to gas is straightforward, presented an immediate way of delivering that requirement.[7]

The CPF was intended "to support and provide certainty for low carbon investment" (HM Treasury, 2010) and increase to £30/$tCO_2$ in 2020 and £70/$tCO_2$ in 2030 (at 2012 prices), driving £30–40 billion in new investment or the equivalent of 7.5–9.5 GW of new capacity (HoC Library, 2018). To achieve these levels, a GB-specific "Carbon Price Support" (CPS) is applied on top of the EUA price set in the EU ETS market. Initially, at least, the CPF rose: after the first year, it doubled from roughly £9/$tCO_2$ to just over £18/$tCO_2$.

In the 2014 Budget, however, the Chancellor of the Exchequer announced that the GB CPS would be capped at the rate in effect at that time of £18/$tCO_2$ over the period 2016-17 through 2019-20 as an addition to the EUA price. In the 2016 Budget, this was extended up to 2021 (HMRC, 2017). The justification was that "EU ETS carbon prices are now substantially lower than was expected when the CPF was introduced. If kept in place, the current CPF trajectory would cause a large and increasing gap between the carbon price faced by UK energy users and those faced abroad" (HMRC, 2014). As of May 2018, the total carbon price arising from the EU ETS plus the GB CPS was around €33/$tCO_2$.

Figure 1 shows the dramatic impact of the GB CPF on the generation fuel mix, with a rapid decline in the coal share from 41% in 2013 to less than 8% in 2017. Prior to 2013, coal

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[6] The Conservative Party had included reference to a floor price in its election manifesto as part of a commitment to replace the Climate Change Levy, which had been introduced in 2001 as a levy on all non-domestic energy users including nuclear power (Johnson and Levell, 2010).

[7] The CPF does not currently apply to Northern Ireland, as the Irish Republic would not impose a corresponding CPF (both are part of the Single Electricity Market on the island of Ireland).

was cheaper than gas: the clean spark spread (wholesale price minus generation cost of a combined cycle gas turbine (CCGT), including carbon costs) was low and often negative, while the corresponding dark spread for coal was positive. After 2013, however, the coal spread fell and became negative in most hours after 2015, so that natural gas has gained share from coal (which is now only run in peak hours). At the same time, the rapid growth of renewables has been displacing other generation, including coal and gas plant, to an increasing extent. Finally, net imports to Britain have risen, recently notably via interconnectors with the Single Electricity Market (SEM) of the island of Ireland.

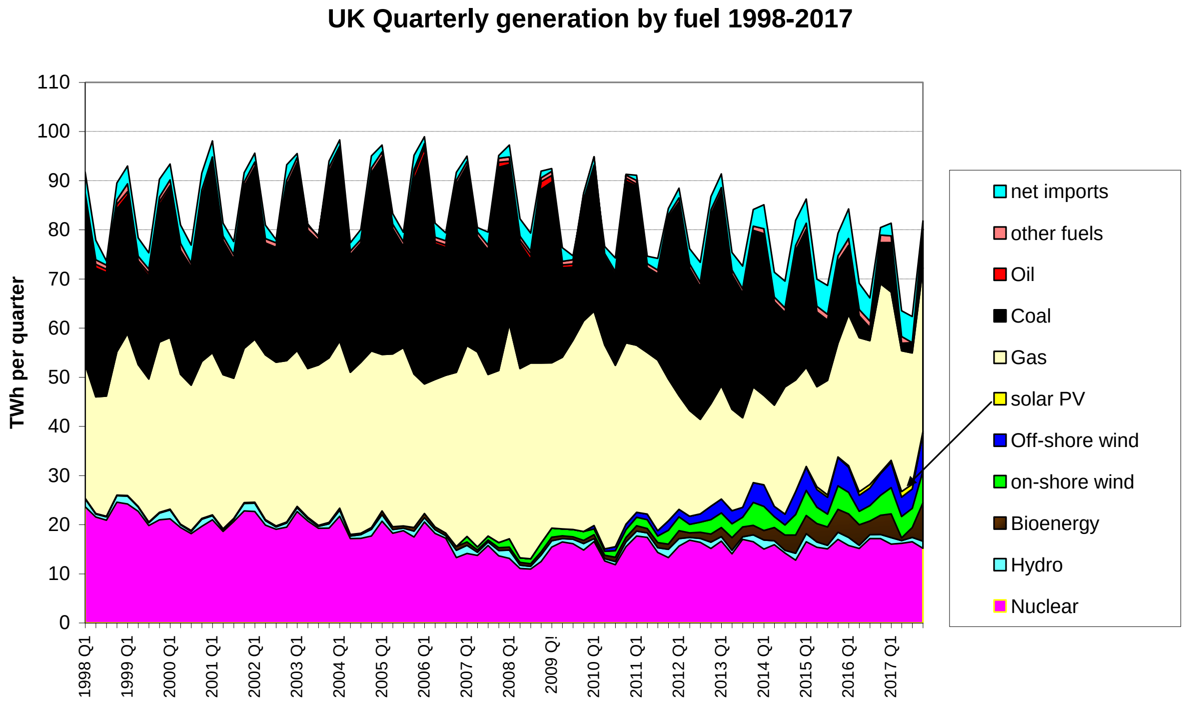

**Figure 1.** Fuel mix in UK electricity generation, 1998Q1–2017Q3
Source: *Energy Trends*, December 2017, Table 5.1 (excludes pumped storage)

It is likely that the CPF has raised the wholesale price of electricity. Much, though not all of the time, coal-fired generation is the marginal fuel; with its emissions rate of 0.9 tonnes $CO_2$/MWh and a CPS of £18/t$CO_2$, this would further increase the wholesale price by £16.2/MWh. By contrast, natural gas at 0.45 tonnes $CO_2$/MWh would raise prices by £8.1/MWh.[8] Some indication of the carbon intensity of marginal (price-setting) generation comes from analysis of the marginal carbon abated by wind power (Thomson et al., 2017). In a period of low coal prices (during which gas is at the margin) the marginal displacement factor fell from 0.6 t$CO_2$/MWh in 2009 to 0.48 t$CO_2$/MWh in 2014, while the marginal emissions factor from increased demand fell from 0.66 t$CO_2$/MWh in 2009 to 0.50

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[8] These calculations assume 100% pass-through from changes in marginal cost to changes in the wholesale electricity price. This is consistent with empirical evidence, for example, on pass-through in the EU ETS (e.g., Sijm, Neuhoff and Chen, 2006; Fabra and Reguant, 2014).

$tCO_2$/MWh in 2014 (close to that of gas). Since this period, coal is more often marginal and this will have likely increased these marginal intensities.[9]

At the time of its introduction, criticism of the GB-only CPF came from both left-leaning and environmental groups on the one hand and consumer groups and Conservatives on the other. Environmentalists raised concerns that at an EU-level, the national CPF would not cut overall reductions but would simply raise prices in GB and thereby further depress the EUA price (Maxwell, 2011). Relatedly, at the European level, national interventions such as the GB CPF were seen by some as undermining the EU ETS (Bausch et al., 2017). These concerns are related to the "waterbed effect": unilateral action that takes place within an individual EU ETS country or sector reduces only *domestic* emissions—but does not reduce *EU-wide* emissions (as these are fixed by the ETS cap).

On the other side, the UK acting alone was seen as harming UK competitiveness and rising consumer bills (Grimwood, 2017). To overcome competitiveness concerns, the Government set up a scheme to partially compensate British energy-intensive industries for the cost of the EU ETS and CPF. By contrast, several electric utilities and NGOs, led by SSE, advocated strongly in support of the CPF as a mechanism to encourage low-carbon investment and lobbied for these price signals to be extended (Sandbag et al., 2017).

### 2.3. International policy experience with carbon price floors (and ceilings)

We begin by discussing policy initiatives for a CPF in key European countries, and then turn to international experience beyond Europe. To date a CPF has been implemented using three different mechanisms (see Wood and Jotzo, 2011). First, an *auction reserve price* creates a minimum price below which a government withholds a number of allowances from sale.[10] Unsold permits may be set aside for future use or retired, either immediately or at a later date. A reserve price does not set an absolute floor because the market price can temporarily drop below it; nonetheless arbitrage between the daily market and future auctions should prevent prices from falling far below the floor.[11] Second, a "*top up" carbon price* is designed either as a tax that makes up the difference between the CPF level and the ETS allowance price or as a (possibly periodically re-set) fixed price which is added to it (as in GB). Third, under a system of *permit buybacks*, the market operator commits to buying back permits at the floor price, thereby reducing the volume available in the daily market (Hepburn, 2006).

*The Netherlands*

The Dutch Coalition talks during 2017 led to a CPF emerging as a central plank of the new (so-called Rutte III) government policy to reduce greenhouse gas emissions by 49% by 2030.

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[9] There does not appear to be a single *ex post* econometric analysis in the literature of the performance of a CPF—even though Britain's CPF has been in place for over 5 years.

[10] In cap-and-trade systems, the market price of an allowance is determined in daily trading among market participants; in addition, there are periodic auctions in which a government sells larger allowance allocations at auction-determined price. In the EU ETS, auctioning is the dominant allocation mechanism for the electricity sector.

[11] The use of a reserve price is common in auction design across many domains and as such does not contradict "market principles". Auction theory shows that setting a reserve price is often optimal for a seller wishing to maximize auction revenue. Auction practice reveals that reserve prices are widely used, e.g., in the sale of real estate, works of art, and auctions of companies. See Klemperer (2004).

A previous "coal tax" had driven out older coal plants though an exemption had left in place newer plants with efficiency above 38% (Marshall, 2015). The new CPF has been designed to encourage the retirement of the five remaining Dutch coal plants. The floor price would apply to the power sector and rise from €18/t$CO_2$ in 2020 to €43/t$CO_2$ in 2030, generating revenues of €630 million (VVD et al, 2017). The Dutch policy is expected to be a top-up tax added to the price realised in the EU ETS. The Coalition Agreement expects to save 12 Mt $CO_2$ by 2030 by shutting down coal-fired stations, a further 2 Mt $CO_2$ through carbon capture and storage (CCS) at waste generation facilities producing electricity, and 18 Mt $CO_2$ from industry CCS. It is still unclear, however, to what extent the CPF will be relied upon to drive this investment and facilitate the coal phase-out—or whether the Dutch Government will enact additional measures to support the transition.

### *France*

In April 2016, pointing to the low EUA price, the French Government under Francois Hollande supported a domestic carbon price floor of roughly €30/t in the power sector; this was aimed largely at pushing coal out of the fuel mix and taking a leadership role within the EU (Fjellheim et al., 2016). Segolène Royal, the Environment and Energy Minister, tried to extend a CPF across the EU by reaching out to Germany in the hope of creating momentum for action (de Beaupuy and Amiel, 2016). Broader reaction to the French proposal was mixed: the European Commission's Energy Commissioner Miguel Arias Cañete argued in favour of maintaining the existing ETS structure while, at least in principle, Germany expressed a willingness to consider the possibility of introducing a CPF (Georgio, 2016). The CPF was due to be adopted by the French Parliament in November 2016, with a start date of January 2017, but resistance from firms with gas-fired generation led to the measure first being restricted to coal. Then, Uniper (formerly E.ON) threatened to shut down its two remaining coal-fired plants. The French Government decided to postpone a unilateral CPF, citing state aid concerns and impacts on jobs (Felix et al, 2016). Nevertheless, in late 2017, President Macron called an EU-wide carbon price of at least €25–30/t$CO_2$ essential to drive investment in energy efficiency and low-carbon technologies (Felix, 2017).[12]

### *Germany*

The issue of a CPF has risen up the German policy agenda (Egli and Lecuyer, 2017) and was a key topic in the 2017 Federal election. The Green Party was supportive while the Free Democrats (FDP) wanted to expand the EU ETS by sector but were opposed to a national or regional CPF (Rueter and Russell, 2017). During the campaign, the two largest parties, Chancellor Merkel's governing Christian Democrats (CDU) and the Social Democrats (SPD) remained equivocal with regard to a CPF and coal more generally (Argus, 2017; Timperley, 2017). In the end, agreement was reached to establish a special commission and a plan "for the gradual reduction and phase-out of coal-fired power production, including an end date" but without a specific mechanism to accomplish the phase-out. The CDU and SPD also agreed to intensify cooperation with France on setting a $CO_2$ price where the "leading

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[12] Similarly, the Nordic Council's 2017 strategic review of energy cooperation highlighted the benefits of a carbon price floor (Kirk, 2017).

principle" would be "strengthening the EU ETS" (Amelang et al, 2018). However, as evidence of rising support for a CPF, in May 2018, the SPD's Grundwertekommission or 'Basic Values Commission' wrote to President Macron to support the introduction of minimum $CO_2$ prices in the EU ETS in a "coalition of the willing and the responsible".[13]

*California & Western Climate Initiative (WCI)*

The WCI was developed in 2007 by four western US states and expanded in 2008 to include two additional US states and four Canadian provinces. In 2011, as California and Quebec moved ahead with their cap-and-trade systems, the other US states withdrew. Ontario remained and eventually created its own cap-and-trade system, which began operating as of January 2017 (although the main opposition party has threatened to replace it with a carbon tax). California sets an auction reserve price in its ETS, introduced at \$10/t$CO_2$ in 2012 and rising at 5% per year (on top of adjusting for inflation). In 2017, the California Supreme Court rejected a suit from the Chamber of Commerce that claimed that the cap-and-trade system with a CPF effectively imposed an illegal tax on business (Fehrenbacher, 2017). The Californian ETS price has generally stayed above the reserve price except for a period in the first half of 2016. The other members of the linked system, Quebec and Ontario, have similar arrangements. The WCI ETS is notable in that it covers 85% of GHG emissions.

*Regional Greenhouse Gas Initiative (RGGI)*

RGGI covers power sector emissions from Northeast and Mid-Atlantic US states. Its auction reserve price was set at \$2.3/t$CO_2$ in 2014, rising at 2.5% annually to roughly keep up with inflation. Without it, the carbon price would have fallen to near zero when emissions dropped below the cap following the recession and decline in natural gas prices (Aldy and Stavins, 2012). In late 2017, RGGI created an "Emissions Containment Reserve" (ECR) which sets aside 10% of the allowances to be auctioned; these will be subject to a floor price of \$6/t$CO_2$ beginning in 2021, with the price rising by 7% per year thereafter (Watson, 2017).[14] Any ECR allowances not auctioned will be deleted. The ECR is supplemented by a "Cost Containment Reserve" (CCR) set at \$13/t$CO_2$ from 2021, also rising by 7% per year, thus creating a price corridor of \$6-13/t$CO_2$ from 2021, rising at 7%.

*Canada*

Canada's two most populous provinces – Ontario and Quebec – already participate in the WCI, whereas the next two largest provinces, British Columbia and Alberta, have instituted carbon taxes rather than an ETS. By contrast, other provinces, notably Saskatchewan, have steadfastly opposed carbon pricing. In October 2016, the Federal Government put forward a "Pan-Canadian Approach to Pricing Carbon Pollution" (Government of Canada, 2016) to ensure that every province (and major emitters therein) would be subject to a minimum benchmark carbon price. Driven in part by concerns over competitiveness, this benchmark allows each province to independently develop their own climate policy while ensuring that a

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[13] See the 'Response to President Macron' of the SPD's Grundwertekommission, at: https://grundwertekommission.spd.de/fileadmin/gwk/Workshop_Wirtschaft_Finanzen/Antwort_an_MacronV_GWK_01.pdf (in German)

[14] Two smaller states in RGGI, New Hampshire and Maine, will not implement an ECR.

federal carbon pricing backstop system operate in any province or territory that does not have a carbon pricing system (meeting the benchmark) in place by 2018 (Parry and Mylonas, 2017). The backstop mechanism is made up of two elements: (i) an output-based pricing system for industrial facilities that emit above a certain threshold and (ii) a carbon levy applied to fossil fuels. The levy starts at C$10/t$CO_2$ (€6.43) in 2018 and rises by C$10 per year to reach C$50/t$CO_2$ (€32.17) in 2022 (Environment and Climate Change Canada, 2018). From 1 January 2019, any province or territory without a system in place that meets the federal backstop price will be supplemented as necessary.

*United States*

During the Obama Administration, various proposals offered in the US Congress included a carbon price floor (and ceiling). The American Clean Energy and Security Act (Waxman-Markey Bill), passed by the House of Representatives in 2009 but never taken up by the Senate, set a reserve price for permit auctions to start at $10/t$CO_2$ (increasing each year by 5% above inflation). This would provide a floor on the carbon price as long as enough permits are auctioned (rather than given out for free or more cheaply available via international offset system). The American Power Act (Kerry-Lieberman Bill) would have set a reserve price at $12/t$CO_2$ (increasing at 3% above inflation). The perceived need for a price floor or reserve was in part driven by lessons drawn from the EU ETS experience and the need to ensure some degree of price stability to encourage investment (Handley, 2009). Although there are no immediate prospects for action on climate change in the US, any future efforts will likely draw on past legislative efforts.

*Australia*

During 2012 to 2014, permit prices under the Gillard government were fixed at A$23/t$CO_2$e (€14.71), creating a de facto price instrument (Jotzo, 2012). Nevertheless, the fixed price did little to incentivise low-carbon investment in a highly politicized debate over climate change. Opposition Leader Tony Abbott threatened to overturn the “carbon tax” as Prime Minister (Teeter and Sandberg, 2016); in 2014, he repealed the carbon permit-tax system as his first act on assuming office. Previously, Australia was expected to remove its price floor in order to link up to the EU ETS (Carbon Market Watch, 2015).

*New Zealand*

New Zealand is one of few jurisdictions to have enacted a ‘fixed price option’, effectively a price ceiling, at NZ$25/t$CO_2$ (€14.91). Faced with low and declining carbon prices, the government over 2015-16 held a consultation, and one of the key questions was whether to institute a CPF: “With the current design of the NZ ETS, implementing a price floor would be challenging and expensive for the Government. The simplest way to establish a price floor would be for the Government to have a standing offer to buy NZUs at the floor price” (New Zealand Government, 2015). A wide range of views emerged, with 25% support for a price floor, 20% for a ceiling, 30% for a price corridor—while 25% were opposed to any intervention in the carbon market (New Zealand Government, 2016). In the end, as a relatively small economy, the main focus was on compatibility with other potential systems; the government decided against a price floor and to adjust its price ceiling.

*Beijing pilot ETS*
In the Beijing pilot ETS, there is a form of carbon price corridor: the Development and Reform Commission can auction extra allowances if the average price exceeds CNY 150 (EUR 20.30) for ten consecutive days and buy back allowances if the price is below CNY 20 (EUR 2.70) (ICAP, 2018).

In sum, international experience shows that a CPF can serve as a practical element of ETS design, while retaining the appeal of a market-based abatement mechanism. This practical experience did not exist when the EU ETS was originally designed in the 2000s. CPFs that apply to an entire ETS have been designed in various ways, via an auction reserve price (WCI, RGGI) or as a top-up payment (Canada) or as permit buybacks (Beijing). CPFs that cover only the power sector have been conceived as top-up payments (GB, Netherlands) as an auction reserve price does not work straightforwardly without full sectoral coverage.

## 3. Political economy analysis of a carbon price floor

In this section, we begin by synthesizing the economic analysis on the choice between price and quantity instruments in climate policy; we then present a political-economy analysis of both an EU-wide and a national CPF in light of multiple market and policy failures.

### 3.1. Economics of instrument choice: Prices vs quantities

Without corrective policy measures, the market mechanism fails to deliver the efficient level of carbon emission because emitters are not charged for the external damages they cause. The appropriate economic instrument is a corrective charge on emissions which internalizes this cost, as recognized in the “Polluter Pays Principle”. If set at the right level, i.e., at the social cost of carbon (SCC), and with the right scope, i.e., for all emitters globally, such a carbon charge corrects the market failure. Over time, this carbon price would rise at the social discount rate, encouraging timely new investment in carbon abatement.

A carbon price can be either delivered by capping the emissions quantity and then trading allowances, as in the EU ETS, or by fixing the emissions price through a carbon tax. In a stylized benchmark case with no uncertainty over abatement costs or benefits, these two instruments are equivalent: a particular price pins down a particular quantity (and vice versa). In a classic paper, Weitzman (1974) compared these two approaches in a simple setting where: (i) there is uncertainty about the *ex post* cost of emissions abatement, and (ii) in making their abatement decisions, firms have better cost information than the government. The government’s objective is to maximize welfare, that is, the difference between the benefits and costs of emissions abatement. The main insight is that setting a tax is superior to setting a quota if the marginal damage of emissions is flatter than the marginal abatement cost schedule. Hence our analysis points to the advantage of an instrument that fixes the carbon price: the marginal damage of $CO_2$ now is essentially the same as that in 10 years’ time, given the long resident times of $CO_2$, even if the marginal damage steeply increases in the *stock* of emissions (Grubb & Newbery, 2008).[15]

Figure 2 illustrates this analysis. At the time of the policy choice, the best estimate of the uncertain marginal abatement cost (MC) intersects the marginal damage (MB) at quota *Q* and tax *t*. The *ex post* correct marginal abatement cost intersects MB at *Q** and *t**. The deadweight loss of setting a quota (i.e., the extra cost of abating *Q* instead of *Q**) is the large shaded triangle ("efficiency loss from quota") while the deadweight loss of a tax is the shaded triangle ("efficiency loss from tax") which is much smaller.

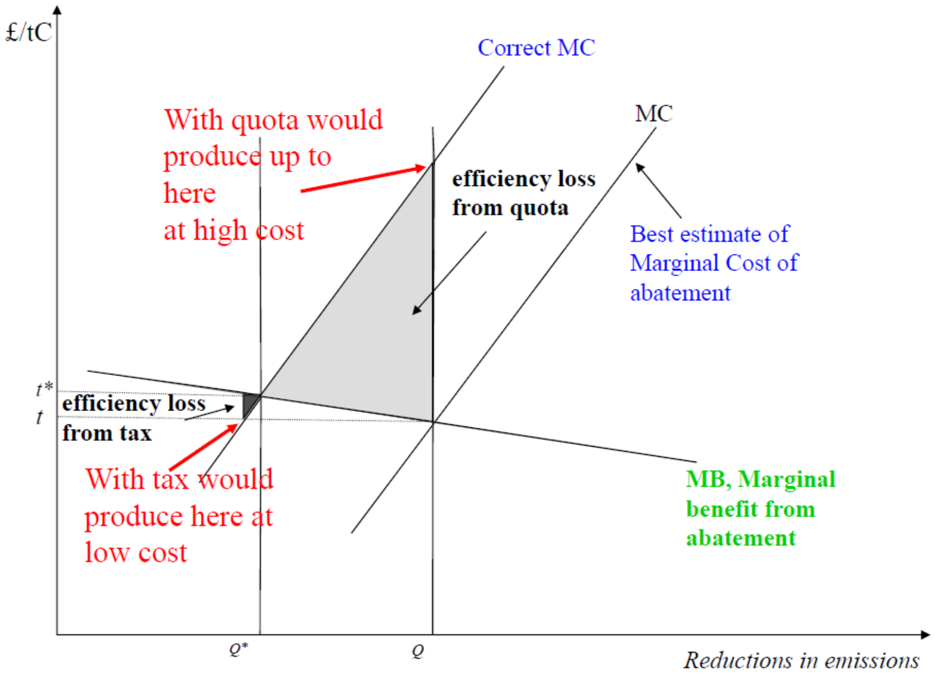

**Figure 2**. Efficiency loss under uncertainty of a carbon tax relative to a carbon quota

Previous studies have examined instrument choice in dynamic settings in which the environmental damage depends on the stock of pollutant, not the flow. Weitzman's (1974) analysis assumes that uncertainty is resolved immediately after abatement choices, so applies directly only to flow pollutants (like noise). Pizer (2002) employed a modified DICE model (Nordhaus, 1994) and found a welfare gain from the optimal price five times larger than setting the optimal quota. Subsequent models (Hoel and Karp, 2002; Karp and Zhang, 2006; Karp and Zhang, 2012) address the role played by new information and learning; they also find that carbon taxes are welfare-superior to quotas, although taxes may be time-inconsistent and therefore subject to credibility issues. Slechten (2011) argues that investments should be front-loaded because learning-by-doing reduces subsequent abatement costs, although this is an argument for subsidizing such spill-overs, rather than relying solely on a carbon tax.

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[15] Conversely, fixing the quantity of emissions becomes preferable close to a "tipping point" at which climate damages escalate sharply. The aim to limit global temperature rises can be translated into a remaining carbon budget; for the Paris Agreement this leads to 395-455 billion tonnes of carbon, as suggested by Goodwin et al., 2018), which in turn can be translated into the point at which the marginal damage becomes very steep. See also Weitzman (2011) on the implications of "fat tailed" uncertainty for climate-policy design.

Similarly, the presence of risk aversion favours taxes over trading (Baldursson and von der Fehr, 2004).

A resolution of the apparent conflict between the objective of limiting the quantity of *cumulative* emissions and the argument above for a carbon price rather than quota on the *rate* of emissions is a hybrid scheme in which there is a carbon price floor, a quota and a ceiling (Roberts and Spence, 1976; Pizer, 2002; McKibben et al., 2009). Such a "price collar" avoids weaker-than-expected economic conditions leading to weakly binding (or even non-binding) constraints. It also avoids the carbon price reaching "too high" levels by giving polluters the option to buy permits at a fixed maximum price, and thus guards against excessive abatement costs—sometimes termed a "safety valve" (Pizer, 2002; Jacoby and Ellerman, 2004; Aldy et al. 2003). In the limit, where the ceiling and floor prices are set at the same level, the ETS with a price collar becomes equivalent to the carbon tax.

A hybrid price-quantity scheme can be seen as an approximation to a rising marginal damage curve (provided the price ceiling is set high enough). It better approximates the shape of the climate-damage function than an ETS or a tax can individually. A tax mimics a horizontal damage function (i.e., the damage done by an extra ton of emissions is constant) while a quota mimics a vertical damage function (i.e., exceeding a critical point leads to a sharp increase in damages). By contrast, a hybrid scheme can mimic a step-wise increasing marginal damage function—which is likely closer to the actual nature of climate damages. A carbon price floor is a simple hybrid design that, importantly, can be introduced within the *existing* EU ETS policy framework (rather than requiring a full transition to a carbon tax).[16]

In sum, this analysis suggests that there is a good case for the introduction of a price element—and a hybrid ETS design featuring a price floor is the preferred way to deliver this.

### 3.2. Analysis of an EU-wide carbon price floor

We now analyze an EU CPF that applies to the electricity sector across all Member States. This policy has the obvious appeal of eliminating the concern that cross-border trade within the Integrated Electricity Market (IEM) is distorted by unequal carbon prices.[17]

For electricity generation, a carbon price plays two distinct roles. In the short run, it affects emissions from existing plant; in the longer run, it guides the choice of plant to install and retire. The short-run impact raises more strongly the variable cost of plant with higher carbon intensities; hence it substitutes via the merit order from higher- to lower-carbon-intensive plant, thus immediately reducing emissions as shown in Figure 1.

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[16] Why then did the EU choose an ETS? It is politically simpler to *introduce* trading with many permits freely allocated to polluters than to impose a carbon tax (Hepburn, Quah & Ritz, 2013). Moreover, consumers often fail to recognise that free permits do not prevent price rises for carbon-intensive goods—while $CO_2$-emitting companies devote considerable resources to lobbying.

[17] Although cross-border electricity trade has increased dramatically in recent years, the vast majority of trading occurs within the confines of countries that fall within the EU ETS. Norway has (or will have) interconnectors to several EU Member States but has long been part of the EU ETS. Similarly, the Swiss ETS is now linked to the EU ETS. Any EU-wide agreement on a CPF would extend to Norway as well as Iceland and Liechtenstein as these non-Member States essentially apply EU ETS legislation under EEA rules. The Swiss ETS is linked to the EU ETS so coordination with an EU CPF would likely require consultation on the appropriate ETS design adjustments.

A direct argument for an EU CPF is then simply that the EU ETS has not delivered an adequate carbon price on which to justify investment in the durable capital-intensive low-carbon generation needed to meet the EU's decarbonisation targets. The EUA price has fluctuated within a band of €5–10/$tCO_2$ from 2011-2017, well below estimates of the social cost of carbon (SCC) and "target-consistent" carbon prices. Moreover, as there is virtually no forward-trading liquidity beyond a three-year horizon, longer-run carbon prices remain a "missing market". In the short run, the main implication within the electricity sector is too little fuel switching from coal- to gas-fired generation; in the longer run, it is too little investment in low-carbon technologies. An EU CPF can support investment by guaranteeing a minimum return on the emissions reductions achieved. Indeed, results from model simulations confirm that a CPF can raise low-carbon investment in the electricity sector—and help bring it forward in time (Brauneis, Mestel and Palan, 2013).

More broadly, a market failure that distorts investments in electricity generation is a lack of sufficiently distant futures markets for fuel, electricity, as well as carbon. These missing markets tend to raise the cost of capital, thus favouring less capital-intensive investment over the higher capital costs of low-carbon technologies. Yet a private investment in durable assets needs confidence that future prices will be adequate for a sufficient fraction of the lifetime of a generation investment. Long-term contracts can correct for some absent future markets; similarly, a CPF with an appropriate floor trajectory can reduce perceived risk and enhance confidence.

The impact of a longer-term EU CPF that raises the effective cost of carbon for the electricity sector is then: (1) fuel switching from coal to more gas and renewables, (2) increases in the wholesale electricity price (when fossil fuels are price-setting), countering the price-depressing effect of mandated renewables investment via the merit order effect, (3) stronger incentives for low-carbon generation and innovation, with less other financial support needed, (4) lower carbon emissions from the EU power sector, (5) additional tax revenue (at least until the EUA price reaches the CPF), (6) abatement cost inefficiency due to unequal carbon prices in the EU electricity sectors relative to other emissions-intensive industries subject to the EU ETS.

The design of such an EU-wide CPF needs to specify its level, rate of increase and duration. As the intention is to help decarbonise electricity and guide low-carbon investment, it should be high enough to discourage base or mid-merit operation of existing coal and lignite stations—and that will depend on the relative prices of coal and natural gas (Newbery, 2016). At 2017 gas and coal prices, a carbon levy to "top up" the EUA price to an initial level of €25–30/$tCO_2$ is probably adequate to yield significant coal-to-gas switching.[18] This price floor could then rise at 3–5% annually above the rate of inflation to converge on the desired medium-run level. This is in line with international CPF experience and with the notion that the carbon price should rise, at a minimum, at the social discount rate. Starting now, it would

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[18] This price for coal-to-gas switching is broadly in line with other recent estimates. National Grid (2016, Figure 9) shows the GB switching values between the prices of gas and coal for a carbon price of €25.9/$tCO_2$; see also IEA (2017a, Box 1.3) for similar estimates. IEA (2017b, Box 11.3) notes that for Europe "a $CO_2$ price in the range of \$50-80 per tonne of $CO_2$ ($tCO_2$) by 2025 would expand the market opportunities for existing gas-fired power plants". In general, the carbon price needed to induce coal-to-gas switching is sensitive to the level of coal and gas prices (Newbery, 2018).

yield a CPF, in real terms, of around €30–40/tCO$_2$ by 2025 and €35–55/tCO$_2$ by 2030. Even if natural gas prices were to rise again, a commitment to this rate of increase until 2030 would likely encourage LEPs to plan on replacing their coal stations with lower-carbon alternatives.

This CPF design is consistent with a proximate objective of addressing the future of coal in the power sector. It is also more practical than any linkage to estimates of the "social cost of carbon" (SCC) as these vary widely, e.g., due to disagreement about the appropriate discount rate and uncertainty around the timing of future climate damages. It is also broadly in line with the "target-consistent" carbon prices that are needed to deliver the EU's climate targets; estimates of these range from €25–63/tCO$_2$ for 2030 and €49–190/tCO$_2$ by 2040 (European Commission, 2011, Table 8, at 2008 prices).

The power-only CPF yields carbon prices that are differentiated across sectors, with a non-traded sector (electricity) facing a higher carbon price than traded sectors (such as steel) within the EU ETS. While this sacrifices some abatement-cost efficiency, it can still be a good policy design in a world in which (a) other non-EU countries pursue only weak climate policies, and (b) trade policy does not correct for international differences in carbon prices via tariff adjustments (Hoel, 1996), i.e., carbon leakage remains an issue. This argument helps justify a higher power-specific EU carbon price, at least for the foreseeable future.[19]

Such an EU-wide CPF should from 2019 also be compatible with the EU ETS's new Market Stability Reserve. The CPF simply guarantees a minimum carbon price, regardless of how effective the MSR turns out to be. If the MSR raises the EUA price by more than anticipated, the CPF for the power sector may simply become non-binding—at least for a period of time. However, in addition, an EU CPF would also help anchor carbon price expectations for the power sector beyond 2030.[20]

The remaining issue, then, is the impact of this EU power sector CPF on overall EU-wide carbon emissions. Consider the benchmark in which the EU ETS cap is fixed and binding. Then the waterbed effect is complete: the reduction in EU power sector emissions releases EUAs from Large Electricity Producers (LEPs), lowers the carbon price until other sectors within the EU ETS buy them—and thus creates a countervailing increase in emissions from these other sectors. (Put differently, the intra-EU rate of carbon leakage here is 100%.) Hence, to achieve the desired climate benefit, at least in the short term, the EU CPF needs to go hand-in-hand with a reduction in the EU ETS cap or a mechanism for cancelling the additional allowances released.[21]

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[19] To some extent, this sectoral differentiation of the carbon price already exists in the EU ETS because: (1) firms in trade-exposed sectors receive higher free permit allocations than electricity generators, and (2) free permit allocations are now partly linked to a firm's output. The output-based allocation effectively waters down the marginal carbon price faced by trade-exposed firms. Performance standards typically lead to quite diverse shadow carbon prices.

[20] If applied to *all* sectors covered by the EU ETS, an EU-wide CPF could, in principle, *replace* the MSR as a way of ensuring sufficient "tightness" of the EUA market. This would yield a simpler and more direct mechanism to support long-run low-carbon investment. Indeed, other industries such as cement or steel face a comparable problem to the power sector of having to make investment decisions in long-lived capital-intensive assets.

[21] Past climate-related policies have arguably failed to recognize this point. For example, the EU *Renewables Directive* may have had no impact on total emissions, given that the predictable reduction in LEP emissions was not offset by a corresponding reduction in the carbon cap.

A key point is that the new MSR design will partially and temporarily alleviate this waterbed effect. The CPF-induced reduction in EU power sector emissions creates additional surplus EUAs. From 2019, annually 24% of surplus EUAs move into the MSR (dropping to 12% per year from 2024). From 2023 onwards, the MSR then begins cancelling its EUAs. In the medium term, this cancellation reduces the waterbed effect of "sub-ETS" action—such as a sectoral CPF—by an estimated 50–80% (Perino, 2018). Over the longer term, approaching 2030, however, the waterbed is expected to fully re-emerge unless further EUA cancellations are agreed.

To illustrate, suppose that the EU CPF in 2019 creates 100 additional surplus EUAs. Of these, 24 are placed into the MSR for later cancellation. However, in 2020, 24% of the remaining 76 EUAs, that is, a further 18.24 EUAs move into the MSR. After 4 years, almost 67% of the original 100 extra EUAs are in the MSR and likely to subsequently be cancelled; thereafter 12% are transferred annually, so that 84% of the original emissions cut should be cancelled by 2030. Put differently, the waterbed effect is only 16% for a near-term emissions cut. In short, the new MSR means that an EU CPF for the power sector creates a substantial climate benefit.

Preferably, the EU CPF would be designed in a way that *fully* offsets the waterbed effect by making the required adjustments to the ETS cap over its trajectory. Ideally, the EU would issue a Directive that binds all Member States to an agreed price floor trajectory or incorporates an EU-wide CPF into a further EU ETS reform package. Perhaps European regulatory and coordinating bodies, such as ACER, CEER and ENTSO-E, can agree on the need to decarbonise LEPs using a CPF.[22]

In sum, an EU CPF can fill the "missing market" of longer-term carbon prices and bring forward low-carbon investment; it is a "low regret" policy that directly addresses the risk of a "too low" carbon price and remains valuable even if other reforms gain pace.

### 3.3. Analysis of a national carbon price floor

Individual EU countries are free to introduce a national CPF to signal their dissatisfaction with the EU ETS—to achieve a higher domestic carbon price and provide greater investor certainty. Since this also raises additional government revenue during a period of fiscal stringency, it offers a model that some countries might find doubly agreeable (even if the underlying tax base will shrink over time), particularly if it leads to the cancellation of a high fraction of the surplus EUAs. It is perhaps no coincidence that a national CPF has been adopted by countries with serious longer-term climate targets: the UK commitment to 80% reduction by 2050 through its *Climate Change Act* and independently-set carbon budgets and the Netherlands adopting a firm 49% target by 2030.

Over the longer run, even within a single country, there is a good case for signalling future carbon prices with sufficient credibility to avoid costly lock-in to what are likely to be

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[22] It is also worth bearing in mind the potential for unintended consequences in the interaction between multiple policy instruments (Bennear and Stavins, 2007). For example, an EU CPF would likely bring windfalls to some existing low-carbon support schemes designed to address an inadequate EUA price—which, in turn, might undermine its political support. However, this seems less of a problem with renewable support schemes that fix the price at which they can sell, such as the widely adopted feed-in tariffs and contracts-for-difference (CfDs).

unsustainable technologies. An ambition to cut GHGs by 80% by 2050 requires an almost complete decarbonisation of the electricity sector, and the generation to achieve this must be installed from now on and needs to deliver low-carbon LEPs rapidly. Figure 3 shows how, under its Two Degrees Scenario, National Grid's *Future Energy Scenarios* see the UK's carbon intensity falling to 50gm/kWh by 2030, with no new coal plant built and renewables replacing gas. The picture is similar for other European countries but delivering on climate targets requires carbon prices many times higher than pre-2018 EUA prices. This creates a need to otherwise signal that all new generating investment (except perhaps for peaking plant running only a few hours per year) must be low or zero carbon.

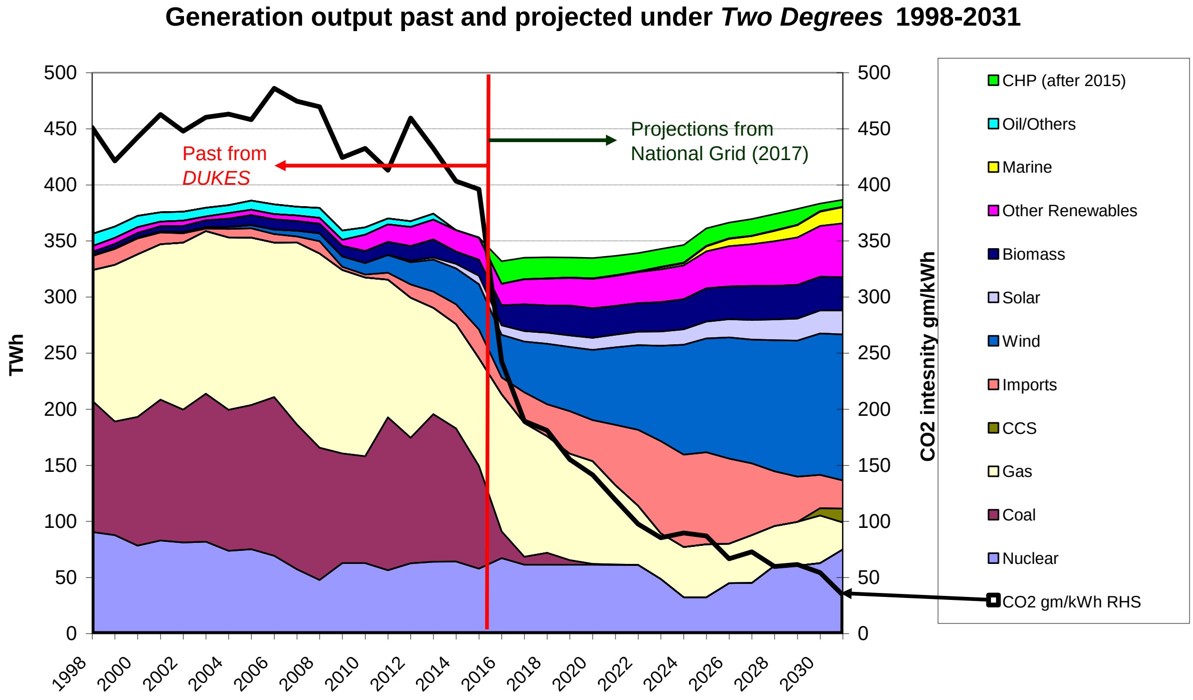

**Figure 3**. Historical and projected fuel mix in UK electricity generation under "Two Degrees" scenario

Source: National Grid (2017), *Future Energy Scenarios*

The justification for a national CPF is that it is politically more feasible, in the short term, than a wider European CPF. Indeed, the political economy of an EU CPF is enormously challenging: Agreement on EU ETS reform has been so difficult because preferences for stringent carbon policy vary widely across Member States. For that same reason, reaching agreement on a *Climate Action Regulation* (also known as the *Effort Sharing Regulation*) to divide up the EU's 2030 commitment to a 40% reduction overall has been so slow (Erbach, 2018). In short, the trade-off between a CPF and an EU-wide policy is higher feasibility at the expense of greater intra-EU trade distortions.

We suggest that the design of a national CPF takes a similar form to the EU-wide CPF above: a carbon levy to "top up" the EUA price to an initial level of €25–30/t$CO_2$, rising at 3–5% annually above inflation, at least up to 2030. In practice, there may be some modest variation to this guideline on the carbon price trajectory depending on the particular country in question, for example, due to the particular characteristics of its fossil fuel generation assets (e.g., the relative efficiency and capacity levels of coal and gas plant).

The domestic impacts of such a national CPF on the power sector are likely to be similar to those of an EU CPF: (1) fuel switching from coal to more gas and renewables, (2) increases in the wholesale electricity price; (3) stronger incentives for low-carbon generation, with less financial support needed, (4) lower carbon emissions from the power sector, (5) additional tax revenue. Any national climate policy faces additional challenges: as noted by Fankhauser, Hepburn and Park (2010), the 'stacking' of multiple national carbon policies alongside a multi-country ETS leads to greater abatement cost inefficiencies.[23] In particular, a (binding) national CPF will typically mean that: (a) its electricity generators now face a different carbon price from the power sector elsewhere in the EU, and (b) its share of the EU power sector faces a different carbon price than emissions-intensive industries across the EU other than electricity (as previously with an EU-wide CPF). The magnitude of these knock-on effects now also depends on the degree of interconnectedness of the particular country with the rest of the EU (and on whether its neighbours also have a similar national CPF or a border tax adjustment on electricity imports from non-CPF jurisdictions is put in place).

As Edenhofer et al. (2017) note, '[w]ithout compensatory measures, voluntary unilateral emission reductions within Member States (e.g. UK carbon price support, potential German coal power exit) dampen short-term allowance prices and shift emissions in space and time' since they argue that the 'EU ETS has so far not allowed the effective expression of different climate policy preferences across EU Member States'. This point is recognized in the 2017-21 Dutch Coalition Agreement; in pointing out the weakness of the EU ETS, it argues that "the group of leading countries will need to introduce supplementary policy, for instance on buying up ETS emission allowances."[24]

A national CPF for the power sector would lead to a similar waterbed effect to the EU CPF discussed above. For the benchmark case with a fixed and binding ETS cap, the waterbed is 100%.[25] Under the new MSR, it is expected to be substantially alleviated by around 50–80% in the medium term (but could re-emerge beyond 2030). Thus crucially, the MSR also enhances the value of a national CPF.[26] The UK's Committee on Climate Change similarly now considers individual Member State actions that reduce domestic emissions to also have additionality in terms of EU emissions (CCC, 2017, p. 21).

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[23] This benchmark result assumes that the ETS cap remains fixed as additional policy instruments are introduced, contrary to the spirit of the MSR; it also does not incorporate other market or policy failures beyond the climate externality.

[24] From the abridged English version of the coalition agreement, which can be found at: http://www.astrid-online.it/static/upload/coal/coalition-agreement--confidence-in-the-future-.pdf. The full Dutch version can be found at VVD et al (2017).

[25] If the ETS is fixed but not binding at a particular point in time, then a national emissions reduction may lead to a contemporaneous reduction in EU emissions (see also MacDonald, 2016); however, because of emissions banking it is likely that this is offset by higher EU emissions at a later date. The contemporaneous waterbed effect is weakened but over time it could reappear.

[26] Note that this holds even retroactively to unilateral policies enacted in the past; for example, any incremental EUA surplus created by the GB CPF may now work through the MSR and thus end up undoing some of the waterbed effect which this policy likely created during EU ETS Phase 3.

Ideally a national CPF should fully offset the waterbed effect—and aim to have a neutral impact on the EUA price. As recognized in the Dutch policy, this can be achieved by way of additional cancellation of national allowances; indeed, such a supplementary policy is explicitly allowed under the latest EU ETS reforms. The Government would first have to estimate the number of EUAs reduced by the domestic CPF.[27] Two complications now arise. The first is that the fraction of any emissions reduction that will be cancelled by the MSR varies over time and is uncertain when the national CPF is introduced. The second is that any national EUA cancellation works through the MSR in reverse: it reduces the number of surplus EUAs so that some EUAs that would otherwise have been cancelled by the MSR no longer are, in fact, cancelled. Nonetheless, national allowance cancellation—reviewed over time—could be desirable from a climate perspective (even if ensuring full EU-wide cancellation through an extended MSR would be far more individually incentive-compatible).

A lesson from the British experience with a national CPF is that it may suffer from the problems of credibility of any fiscal instrument introduced by a single country. While the original intention was for the CPF to rise very strongly over time (to £70/t$CO_2$ by 2030), this was never enshrined in law—in contrast to the 5 year carbon budgets. The price trajectory was then halted just as it began to rise, without any commitment to maintaining the CPF beyond 2020/21. Binding price floor targets for 2020 and 2030 could have provided credible medium- and longer-term commitment, and these could have largely superseded the need for any other signals, at least in the electricity sector. A carbon price that can be changed each year lacks credibility; reputation can deliver credibility but takes time to build.

Given this lack of credibility, the British CPF was supplemented from the outset, in the 2013 *Energy Act*, by an emissions performance standard (EPS) that ruled out new coal generation. To replace the existing coal, the *Act* set up annual auctions for long-term capacity payment contracts for new flexible fossil generation (HC, 2013). The UK continued to maintain (and even expand) a diverse arsenal of shorter-term climate policy instruments, many of which were directed to other market failures or behavioural biases. Subsequently, the UK Government announced that coal generation would be phased out by 2025 (BEIS, 2018), since updated to 2023.

Will unilateral CPFs within the EU support movement towards an EU-wide CPF or will they undermine it? Governments imposing a national CPF that raises carbon costs significantly above the ETS price may fear that their competitive position is put at risk—unless other countries follow with comparable CPFs under EU direction. Since the French CPF proposal in 2016, NGOs have increasingly embraced the idea of "regional carbon price floors" and pressured for greater government action (Tamma, 2017). Thus, a gradual stitching together of unilateral CPFs from the UK and the Netherlands to other Member States that might be so inclined (such as France or the Nordic countries) provides at least a plausible alternative dynamic that makes an EU-wide CPF more likely over time—without requiring

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[27] The induced emissions reduction can be estimated by using a dispatch model to calculate carbon emissions with and without the CPF; for example, the Single Electricity Market Committee of the Irish electricity market uses Plexos for similar modelling exercises.

the need for consensus and giving veto power to those least inclined towards aggressive climate action.[28]

In sum, a national CPF has the advantage of greater feasibility over an EU-wide CPF but also comes with greater intra-EU trade distortions. Countries with stringent domestic emissions targets may find a national CPF particularly attractive to avoid getting locked into unsustainable technologies and they might further enhance the credibility of their CPF by supplementing it with an EPS.

## 4. Broader interactions with other climate-related policies

### *Coal phase-out and emissions performance standards*

In several jurisdictions, addressing the future of coal has been a key motivation for a CPF. Interest in shifting from coal has continued to accelerate; the UK and Canada were pivotal in recently setting up the *Powering Past Coal* consortium, that now includes over twenty countries,[29] including Belgium, Denmark, Finland, France, Ireland, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Portugal, Sweden and the UK and as well as various sub-national jurisdictions (Chestney et al, 2017). Once coal has been eliminated from the generation mix, the question is whether the lack of that rationale could deprive a CPF of its political legitimacy—even if it will still continue to encourage zero-carbon generation over natural gas.

Like Britain, jurisdictions can set an EPS which, together with the CPF, effectively requires elimination of coal or the use of CCS to reduce the overall emissions intensity. Two cases where an EPS has been used in isolation (without a CPF) are in North America. In Canada, the federal EPS of 420 tons/GWh was implemented in 2015; although the first commercial-scale CCS plant at Boundary Dam was not mandated by it, any subsequent coal plants need to have at least some $CO_2$ capture to meet the standard (Gale, 2015). In the US, the Obama Administration adopted two main regulatory approaches to address the role of coal in the electricity mix: new source performance standards under Section 111(d) of the *Clean Air Act* and a *Clean Power Plan* for existing sources under Section 111(b) (Perlis, 2014). Any new or "substantially modified" coal plant would be required to deploy CCS to stay below the EPS. By contrast, the *Clean Power Plan* set state-level targets for $CO_2$ emissions intensity which could be achieved flexibly.[30]

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[28] Woo et al. (2017) note that California requires out-of-state generators be certified if they are to be counted as "specified" sources subject to unit-specific GHG emissions factors. Washington State therefore exports hydro power to gain higher California prices but locally generates "replacement" power from the same kinds of gas generation which it displaces in California. This might prompt Washington State, faced with increased local emissions, to adopt a similar policy, in which case the short-run distortion might lead to a better outcome over the longer haul.

[29] The current membership list is at: https://www.canada.ca/en/services/environment/weather/climatechange/canada-international-action/coal-phase-out/alliance-declaration.html

[30] States could use a default rate-based standard or an equivalent "mass-based" regulation (such as cap-and-trade) which could be coordinated with other states (Burtraw et al., 2014a). Bushnell et al. (2015) anticipated an average price on the order of $35/t$CO_2$ in a resulting cap-and-trade system, in line with the SCC used by the Environmental Protection Agency in designing the Clean Power Plan.

### *Low-carbon innovation policy*

The EU has several mechanisms explicitly linked to the EUA price to support low-carbon technologies. These funds may motivate others to support a CPF beyond those interested purely in emissions reductions. For example, the NER300 mechanism had set aside 300 million allowances to support CCS, innovative renewables technologies, and advanced biofuels. When its first call for proposals was launched in November 2010, the EUA price was over €15/$tCO_2$ and so the fund was expected to raise close to €5 billion; instead the auctions came in 2013, by which time EUA prices were closer to €7/$tCO_2$, and so raised almost 60% less than originally expected (van Noorden, 2013; Reiner, 2016). The NER300 allocated project funds to 24 of 28 Member States, thus ensuring that there was widespread benefit from the programme (Åhman et al, 2018). Its successor, the *Innovation Fund*, will set aside 450 million EUAs for auctioning to support low-carbon technologies, and the 'modernisation fund' supports energy efficiency in poorer EU countries by auctioning off 2% of total allowances. Revenue from an EU CPF could be a better, more stable source of funding innovation as linking revenue to the price of EUAs means that revenue falls just when the funds are most needed. In contrast, money raised from a CPF rises when needed and falls when less critical. Both funds can help create constituencies to support a broad CPF, including in poorer EU Member States otherwise less inclined towards stronger climate policy.

### *EU ETS linking to other cap-and-trade systems*

Countries need to consider whether a CPF affects plans to link to another ETS. Parry (2017) argues that there is the potential for coordinated carbon price floor arrangements under Article 6.2 of the *Paris Agreement*. A carbon price ceiling, by effectively eliminating a hard cap on emissions, may complicate linking cap-and-trade systems under Article 6. In the WCI, Quebec and Ontario have, by linking adopted California's CPF. New Zealand did not adopt a price floor and plans to modify its price ceiling in order to be compatible with future linking; Australia had planned to remove its CPF to avoid incompatibility with the EU ETS. The issue is perhaps not so much whether a CPF is compatible with the EU ETS but that linking involves decisions on alignment—and the larger ETS can have considerable bargaining power along a number of dimensions including a CPF. However, the UK experience suggests that a national CPF can be adopted without any rebuke from other EU ETS countries.

### *Brexit*

A question mark looming over European carbon markets is the future role of Britain. A "hard Brexit" in which the UK drops out of the single electricity market and the EU ETS (and perhaps even out of coordinating bodies such as ENTSO-E and ACER) could be problematic. There have been moves in the European Parliament to guard against British EUAs flooding the market if it decided to abruptly leave the ETS, although the MSR should mitigate most if not all of these adverse effects. After some initial threats of unilateral action (Brunsden and Barker, 2017) a short-term arrangement was reached between UK and EU-27 negotiators—

although it is still unclear if the UK will remain within the EU ETS after the end of the third phase in 2020 (Krukowska et al, 2017).

The UK has seen the majority of interconnectors built or commencing construction in the last five years, so interconnectors themselves will not be affected under Brexit (Pollitt and Chyong, 2017). Yet if the French proposal for an EU-wide CPF of, say, €30/$tCO_2$ was instituted in 2022, this could create an inefficient asymmetric carbon price at either end of the Anglo-French interconnection—unless the GB CPF aligned itself with the EU-ex-UK CPF. The UK *Climate Change Act*'s trajectory with an 80% reduction target by 2050, supported by five-year carbon budgets determined by the Committee on Climate Change, should prevent the UK from easing its climate ambitions—even following a hard Brexit.

## 5. Conclusions

The EU ETS has so far produced an insufficient price signal to adequately incentivize low-carbon power generation. Recently agreed EU ETS reforms still leave the risk of a too low short-term carbon price and the "missing market" of a longer-term carbon price. This slow progress has led to the UK and the Netherlands opting for a *national* power sector CPF. Others, notably France, have instead emphasised the need for an *EU-wide* price floor. At the same time, the European Commission and leading Member States such as Germany have, officially at least, continued to describe the EU ETS as the central instrument of climate action.

We have argued that an EU-wide CPF for the power sector would constitute a significant improvement to the EU ETS. It would help re-affirm the EU's position as a climate leader and contribute to achieving decarbonisation targets. This CPF is a "low regret" policy: it directly addresses the risk of a too low carbon price and can help reassure investors whether or not other reforms gain pace. Combining it with a carbon price ceiling—to create a price corridor—might also make the policy more attractive to countries concerned about volatile carbon market prices.

We have further argued that individual Member States with more ambitious climate objectives may find a national power sector CPF an attractive and readily-feasible policy to signal low-carbon investment and getting locked into unsustainable technologies. This, in turn, could create a policy dynamic leading to a regional CPF in North-West Europe or to a redoubling of efforts to institute an EU CPF to avoid proliferation of national CPFs.

Our CPF design recommendation is based on inducing coal-to-gas switching, as a carbon levy to top up the EUA price to €25–30/$tCO_2$, rising at 3–5% annually above inflation at least up to 2030. The EU ETS's new Market Stability Reserve will, in the medium term to the mid-2020s, substantially alleviate the "waterbed effect" associated with such additional policies—at the national or sectoral level—that operate within the EU ETS's coverage. Its novel mechanism to cancel EUAs creates a climate benefit—and thus further enhances the value of a CPF.

In sum, a well-designed power sector CPF is increasingly attractive on both political-economy and environmental grounds.

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