The political economy of a carbon price floor for power generation

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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 policy experience with price floors (and ceilings).

Keywords: Carbon pricing, electricity markets, market failure, policy failure, political economy, price floor, price corridor.

JEL codes: H23, L94, Q48, Q54

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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 (EU) has a 40% reduction target for 2030 (relative to 1990 level) and its "Energy Roadmap 2050" aims to reduce carbon emissions by 80-95% by 2050, with the electricity sector decarbonizing earlier and more strongly than other sectors. The pricing of carbon emissions is a key economic instrument to address the market failure associated with the external effects of climate damages.[1] An increasing number of jurisdictions are implementing carbon pricing as a cornerstone of climate policy at national and sub-national levels (World Bank, 2017).

The EU has taken global leadership in carbon pricing, beginning in 2005 with the introduction of its Emissions Trading Scheme (ETS). The EU ETS has, however, so far failed to deliver the carbon price signal 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.[2] Moreover, as there is virtually no forward-trading liquidity beyond a three-year horizon, longer-run carbon prices remain a "missing futures market" (Newbery, 2016). Reforms to the EU ETS have been complicated by its political economy, notably of achieving unanimity across EU Member States for measures "primarily of a fiscal nature" (as described in Article 192 of the Lisbon Treaty (EU, 2007)). The new Market Stability Reserve (MSR), due to begin operation in 2019, increases complexity and may still not ensure a sufficiently strong and durable carbon price signal.[3] 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 (GB) 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 (roughly €20/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.[4] This policy debate sits alongside the

[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 an emissions reduction at least cost to society by inducing the marginal cost of abatement to be equalized across regulated entities. Greater sectoral coverage therefore tends to increase the benefits of market-based policy. Renewable support schemes also play an important role in incentivizing low-carbon innovation.

[2] The low EU ETS price has been driven, in part, by additional policies such as renewable support schemes which reduce emissions demand. See Hintermann, Peterson and Rickels (2016) for a recent overview of the drivers of the EU carbon price. Note that the 43% carbon reduction (relative to 2005) required of EU ETS sectors is stronger than the EU's overall 40% reduction target (relative to 1990).

[3] The MSR has successfully avoided being designated as a fiscal measure over veto concerns (Hepburn et al., 2016, Morgan, 2018). Following agreement on an EU ETS reform package in January 2018, the EU carbon price has risen to around €20/tCO_2 (as of October 2018). We discuss these reforms in Section 2.

[4] Whether adding an EU-wide CPF to the existing system would require unanimity is a matter of ongoing debate since there has been no case law on the subject of what can be deemed "primarily of a fiscal nature". Some have dismissed the possibility out of hand (van Renssen, 2012) whereas others

proximate objective of closing (unabated) coal-fired power generation, which has emerged in several European countries, as well as the promotion of renewable energy technologies.

This paper analyzes the desirability of both national and EU-wide CPFs. Given its central role for early decarbonization, we focus on the electricity sector; in doing so, we sidestep many 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. While our focus is on Europe, our analysis also offers insights for other jurisdictions seeking to implement well-functioning markets to deliver on climate targets.

Our main arguments are as follows. First, there is a good economic case for the introduction of a 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 instrument — which can be more efficient than a pure ETS or a carbon tax alone.[5] 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 makes 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/tCO_2, rising at 3–5% annually above the rate of inflation, at least until 2030. This would yield significant coal-to-gas switching, with immediate CO_2 reductions, and is more practical than relying on contested estimates of the SCC.[6] 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 delivering climate benefits. The reason is that the MSR mitigates the "waterbed effect" whereby unilateral action by an individual EU ETS country (or sector) reduces domestic emissions but not EU-wide emissions—as these are fixed by the overall ETS cap.

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—the climate externality. Second, and related, we combine standard economics with the underlying *political* economy of carbon pricing, including the possibility

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point to either using Section 192(1), which only requires qualified majority, or Section 192(2), which requires unanimity, as the basis for proceeding with a CPF (Weishaar, 2015). The notion of subsuming major changes within the EU ETS as a means of avoiding the unanimity requirement has been made in other contexts, e.g., introducing consumption into the ETS (Ismer and Haussner, 2015). Weisbach (2012) discusses more generally the operation of carbon taxes alongside or within the EU ETS.

[5] This argument is based on the economics of instrument choice under uncertainty (e.g., Roberts and Spence, 1976; Pizer, 2002; McKibben et al., 2009); see Section 5 for details.

[6] Section 6 provides discussion of coal-to-gas switching induced by carbon pricing.

of policy failure (notably in the design of the EU ETS). Third, we update earlier literature in light of recent policy developments; most academic contributions on CPFs date back to the early 2010s or before. [7] Fourth, we focus specifically on the power sector.

Finally, we must acknowledge that our analysis is 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 wider 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 gives background on recent developments in EU ETS reform, Section 3 discusses the British CPF, and Section 4 summarizes international experience with CPFs (and price ceilings). Section 5 presents the case for a "hybrid" ETS design. Section 6 and 7 contain our political-economy analysis, respectively, of an EU and national CPF. Section 8 concludes with policy recommendations.

2. The EU Emissions Trading Scheme: Background, challenges and reform

During the 1980s and 1990s, the EU failed to establish any European-wide energy or climate taxes, with several initiatives failing to secure the unanimity across EU Member States required for measures "primarily of a fiscal nature" (Article 192 of the Lisbon Treaty (EU, 2007)). Although there is still disagreement on what "primarily of a fiscal nature" means (Weishaar, 2018), the EU resorted to a non-fiscal measure in form of the EU ETS, as laid out in a green paper in 2000 which became the ETS Directive (Directive 2003/87/EC). The EU ETS now affects some 13,500 stationary sources in the power sector (for installations above 20 MW) and major energy-intensive industrial sectors, encompassing some 2 $GtCO_2$ annually from EU Member States as well as Norway, Iceland and Liechtenstein (Ellerman et al., 2016).

The EU ETS began with a pilot Phase 1 from 2005–7 during which all emissions allowances were freely allocated to regulated firms. Phase 2 (2008–12, spanning the Kyoto Protocol compliance period) introduced auctioning of up to 10% of allowances as well as a tightened overall emissions cap. The current EU ETS Phase 3 (2013–20) then saw expansion to include domestic EU air travel and some additional energy-intensive sectors.

The run-up to Phase 4 (2021–30) has seen active efforts at EU ETS reform, driven by the low price of allowances (EUAs) which had mostly fluctuated within a band of €5–10/tCO_2 since the early 2010s.[8] A major focus of these reforms has been the accumulated EUA surplus, which rose steadily from 2009 as EUAs continued to be overallocated even as emissions were falling (Convery and Redmond, 2013). The EUA surplus stood at 2 billion after Phase 2, rose to 2.1 billion in 2013 before falling slightly to 1.7 billion by late 2016. However, securing even qualified majority agreement of 28 countries to change the ETS that,

[7] Key early 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 related literature in Sections 4 and 5. 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.

[8] For a brief period, near the beginning of Phase 2, the carbon price was higher, at around €15/tCO_2; there is some evidence that such price levels can drive emissions reductions (e.g., Ellerman and Buchner, 2008; Ellerman, Convery and de Perthuis, 2010; Anderson and Di Maria, 2011) and low-carbon investment (e.g., Calel and Decheleprêtre, 2016)

via its low carbon price, benefits the coal-intensive electricity systems of some EU countries (relative to a world with a high carbon price) has proven challenging.

The European Council set out principles for ETS reform in October 2014, followed by the European Commission offering a proposed Directive in July 2015. The European Parliament and Council laid out their positions in February 2017, leading to six rounds of trilogue. The main debates have been over the rate at which the emissions cap will be reduced (the linear reduction factor), 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 reached between the Council and Parliament in November 2017 and ratified by the Parliament in January 2018. The new EU ETS Directive (Directive (EU) 2018/410) entered into force on 8 April 2018. Since then, the EUA price has risen from around €6/tCO_2 during much of 2017 to around €20/tCO_2 (as of October 2018).

The MSR, originally agreed in 2015, was finally established in January 2018 and begins operations from January 2019. It sought to avoid being designated as a fiscal measure over veto concerns (Hepburn et al., 2016). A recent Polish legal challenge to the MSR—on the grounds that it would significantly alter the energy mix of individual Member States (a national competence) and hence would have needed unanimous rather than qualified majority support—was dismissed by the European Court of Justice (Morgan, 2018). 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 these ETS reforms, especially cancelling surplus EUAs in the MSR, are likely an improvement, concerns remain. First, the MSR as currently conceived will have no long-run effect 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.[9] Third, large uncertainty around the future EUA price remains, notably the risk of it being "too low" to deliver sufficient low-carbon investment. Analyst estimates of future EUA prices vary 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 mixed views of the MSR approach, though many discussions have been sceptical. 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

[9] 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." Perhaps the MSR's opacity reduced the scope for objections during the negotiations on its implementation.

might be negatively affected"; the simulation results of Perino and Willner (2017) suggest that the MSR would have only a very limited impact on EUA prices up to 2037, even under an increased allowance intake. Other papers have taken a more favourable view of the MSR approach (e.g., Neuhoff et al., 2015; Hepburn et al., 2016) in helping to reform an already complex system. 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.

3. The case of the carbon price floor in Great Britain

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. 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 it was the binding obligation imposed by the *Climate Change Act 2008*, requiring Government to demonstrate progress in decarbonising the economy. The electricity sector, in which a fuel switch from coal to gas is straightforward, presented an immediate way of delivering that requirement. The CPF currently applies only to the electricity market in Great Britain (HMRC, 2017); Northern Ireland is exempt as the Irish Republic would not impose a corresponding CPF (both are part of the Single Electricity Market on the island of Ireland).

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 (roughly €20/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 October 2018, the total carbon price arising from the EU ETS plus the GB CPS was around €40 (£35)/tCO_2.

Figure 1 shows the dramatic decline in the coal share from 41% in 2013 to less than 8% in 2017. Part of the reason was rapid growth in renewable electricity and part was due to the considerable decline in electricity demand from 2006 onwards (driven by domestic efficiency gains and continuing de-industrialization). However, a significant driver of the coal decline has been that the CPS moved coal-fired generation from baseload to mid-merit. Prior to 2013, coal 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 mainly run at winter peak hours). Finally, net imports to

Britain have risen, recently notably via interconnectors with the island of Ireland (which is not subject to the CPF).

The CPF has raised the wholesale price of electricity (Chyong, Guo and Newbery, 2018). When coal-fired generation is the marginal fuel at 0.9 tonnes CO_2/MWh and a CPS of £18/tCO_2, this would increase the wholesale price by £16.2/MWh. By contrast, natural gas at 0.40 tonnes CO_2/MWh would raise prices by £7.2/MWh.[10] 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 (MDF) of wind in 2014 was 0.5 tCO_2/MWh, the same as the marginal emissions factor from increased demand. After the total cost of carbon rose substantially after 2015 (and the price of natural gas fell) the MDF fell steadily to 0.35 tonnes CO_2/MWh in 2017 as coal was displaced from its role as the marginal fuel for many hours (Chyong, Guo and Newbery, 2018).

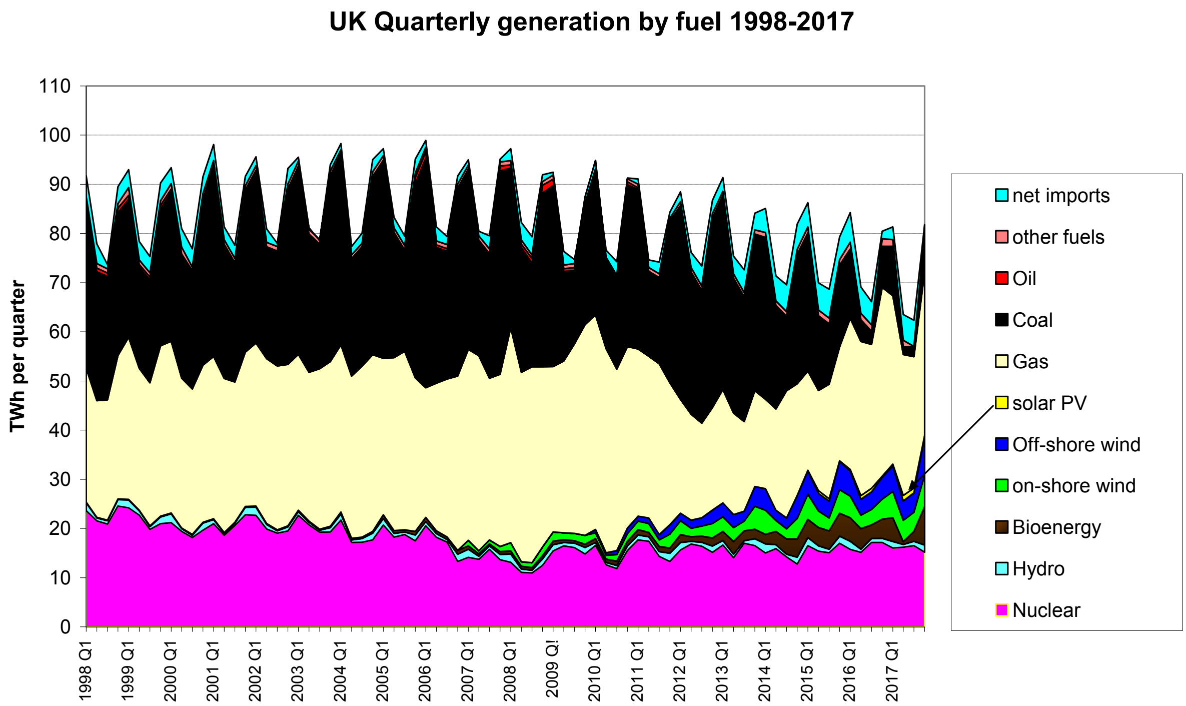

Figure 1. Fuel mix in UK electricity generation, 1998Q1–2017Q3
Source: *Energy Trends*, December 2017, Table 5.1 (excludes pumped storage)

At the time of the introduction of the GB-only CPF, environmentalists raised concerns (Maxwell, 2011) related to the “waterbed effect”: unilateral action by 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). To overcome competitiveness concerns (Grimwood, 2017; Rooney et al., 2018), the Government set up a scheme to partially compensate British energy-intensive industries for the cost of the EU ETS and CPF. Several electric utilities and NGOs, led by SSE, advocated strongly in support of the CPF as a mechanism to encourage

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

low-carbon investment and lobbied for these price signals to be extended (Sandbag et al., 2017). Faced with slow-moving ETS reform and a rising view of the CPF's effectiveness in reducing coal generation, many environmentalists also began to take a more positive view (Murray, 2014). Going forward, some analysts have expressed concern that, without further raising the CPF, higher natural gas prices may lead to a resurgence of coal (Staffell, 2018) whereas others claim that the rising EUA price obviates the need for a CPF (Evans, 2018).

4. 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. 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. 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 fixed price which is added to it (as in Great Britain). 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 et al., 2006).

The Netherlands

The Dutch Coalition talks during 2017 led to a CPF for power emerging as a central plank of the new (Rutte III) government policy to reduce GHG emissions by 49% by 2030. 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 rise from €18/tCO_2 in 2020 to €43/tCO_2 in 2030, generating revenues of €630 million (VVD et al, 2017). It 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. It is still unclear, however, whether the Dutch Government will enact additional measures to support the transition and facilitate the coal phase-out.

France

In April 2016, pointing to the low EUA price, the French Government under François Hollande supported a domestic CPF of roughly €30/tCO_2 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). By May, 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). In July, a government-appointed commission recommended that the EU ETS introduce a price floor beginning at €20–30/tCO_2 in 2020, together with a price ceiling of €50/tCO_2; at a national level, it recommended that France impose an additional tax on coal-fired electricity generation (Mission Report, 2016). Reaction to the proposal was mixed: the European Commission's Energy Commissioner

Miguel Arias Cañete argued in favour of the existing ETS structure while, at least in principle, Germany expressed a willingness to consider the possibility of a CPF (Georgio, 2016). The CPF was due to be adopted by the French Parliament in November 2016 but resistance from firms with gas-fired generation led to the measure being restricted to coal. Then, Uniper (formerly E.ON) threatened to shut down its two remaining coal-fired plants, and 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/tCO_2 essential to drive investment in low-carbon technologies (Felix, 2017).[11]

Germany

The issue of a CPF has risen up the German policy agenda (Egli and Lecuyer, 2017) , including various academic and government advisory boards (Matthes, 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's sectoral coverage but opposed a CPF (Rueter and Russell, 2017). 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). 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—and having removed any reference to a minimum carbon price. The CDU and SPD agreed to intensify cooperation with France on setting a CO_2 price where the "leading principle" would be "strengthening the EU ETS" (Amelang et al, 2018). In May 2018, the SPD's 'Grundwertekommission' wrote to President Macron to support the introduction of minimum CO_2 prices in a "coalition of the willing and the responsible".[12] While there has been no change in the official government position, energy and environment ministers from nine of the 16 Länder in July 2018 wrote in support of the French proposal for a minimum carbon price of €30/tCO_2 (Demirdag, 2018).

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; however, by August 2018, the new provincial Conservative government passed legislation withdrawing the province from the WCI (McCarthy, 2018). The WCI ETS is also notable in that it covers 85% of GHG emissions. California sets an auction reserve price in its ETS, introduced at \$10/tCO_2 in 2012 (around €12.5/tCO_2) and rising at 5% per year (on top of

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

[12] 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)

adjusting for inflation).[13] 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. Other members of the linked system, Quebec and Ontario (for a short time), made similar arrangements. The California system had set an Allowance Price Containment over 2013–2020 which acted as a "soft" price ceiling by requiring reserve allowances to be auctioned if prices rose above a specific level (although they never have). Recent legislative amendments to the cap-and-trade system call for different price containment points as well as for a "hard" price ceiling to be established (CARB, 2018).

Regional Greenhouse Gas Initiative (RGGI)

RGGI covers power sector emissions from Northeast and Mid-Atlantic US states. From 2010Q3 through the end of 2012, the allowance price stayed just below $2 because of the price floor on permit auctions (Fell, 2016). Without the floor, 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). From 2014, the cap was reduced by 45% and the price increased above the floor price in 2013 (Murray & Maniloff, 2015). RGGI's auction reserve price was then set at \$2.3/tCO_2 in 2014, rising at 2.5% annually to roughly keep up with inflation. At the same time, a "Cost Containment Reserve" (CCR) was created, effectively to act as a price ceiling.[14] The CCR has already been triggered on several occasions (such as the March 2014 and November 2015 auctions) (Ramseur, 2017). 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 trigger price of \$6/tCO_2 beginning in 2021, with the price rising by 7% per year thereafter (Watson, 2017).[15] Any ECR allowances not auctioned will be deleted. Thus, from 2021, there will be three mechanisms: an auction reserve to set the price floor and trigger prices for the ECR and then the CCR.

Canada

Quebec already participates in the WCI whereas British Columbia and Alberta have instituted carbon taxes rather than an ETS. Other provinces, notably Saskatchewan, 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 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 federal carbon pricing backstop system

[13] At the Federal level, during the Obama Administration, 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/tCO_2 (increasing each year by 5% above inflation). The American Power Act (Kerry-Lieberman Bill) would have set a reserve price at \$12/tCO_2 (increasing at 3% above inflation).

[14] The CCR trigger price was originally set at $4 in 2014, rising to $6 in 2015, $8 in 2016, $10 in 2017, and increasing 2.5 percent annually thereafter. After the recent reforms, the CCR price will be set at \$13/tCO_2 from 2021, rising by 7% per year.

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

operates in any province or territory that does not have a carbon pricing system 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/tCO_2 (€32.17) in 2022 (Environment and Climate Change Canada, 2018). From 1 January 2019, any province or territory without a system that meets the federal backstop price will be supplemented. However, the provinces of Saskatchewan and Ontario have launched challenges to the power of the Federal government to impose such measures (Rabson, 2018).

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 carbon prices, the government over 2015-16 held a consultation, with a CPF as one of the key questions: "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 floor, 20% for a ceiling, 30% for a price corridor—while 25% were opposed to any intervention (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 (DRC) can auction extra allowances if the average price exceeds CNY 150 (€20.30) for ten consecutive days and buy back allowances if the price is below CNY 20 (€2.70) (ICAP, 2018a).

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.[16] This practical experience did not exist when the EU ETS was originally designed in the 2000s. There has been increasing interest in a CPF in a number of European countries. 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 we discuss in more detail later on, an auction reserve price does not work straightforwardly without full sectoral coverage. Jurisdictions have increasingly combined a price floor with a price ceiling (RGGI, California, and Beijing), partly because this can help increase "buy in" from regulated entities. Moreover, unlike the British CPF, which is subject to readjustment in every annual

[16] We note that there is still a shortage of formal economic *ex post* analysis of the CPFs around the world that have now, in some cases, been implemented for five years or more. This is an important area for future research on carbon pricing. Chyong et al. (2018) examine the British case.

fiscal budget, the RGGI and California price floors (and the pan-Canadian backstop price) now automatically increase on an annual basis at a rate considerably above inflation.

5. The 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 damage they cause. An 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 and over time, such a carbon charge corrects the market failure. Over time, this carbon price would rise at the social discount rate, thereby also 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. Given 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.[17] To maximize welfare, a tax is superior to a quota if the marginal damage of emissions is flatter than the marginal abatement cost schedule. Hence there is an advantage in fixing the carbon price, as the marginal damage of CO_2 now is essentially the same as in 10 years' time, given its long resident times, even if the marginal damage steeply increases in the *stock* of emissions (Grubb & Newbery, 2008).[18]

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, i.e., the welfare loss, of setting a quota (i.e., the extra cost of abating Q instead of Q^*) is the large lighter shaded triangle ("efficiency loss from quota") while the deadweight loss of a tax is the smaller darker shaded triangle ("efficiency loss from tax"), which is much smaller.

Weitzman (1974) assumed that uncertainty is resolved immediately after abatement choices, so applies directly only to flow pollutants (like noise). Subsequent studies examined instrument choice in dynamic settings in which the environmental damage depends on the stock of pollutant, not the flow. 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

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[17] The Weitzman (1974) analysis focuses on a situation in which all regulated firms create the same environmental damage; this assumption is clearly appropriate in the context of climate change.

[18] 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.

carbon taxes are welfare-superior to quotas in a context where the MB schedule is relatively flat, although taxes may be time-inconsistent and therefore subject to credibility issues. Slechten (2013) 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. Similarly, the presence of risk aversion favours taxes over trading (Baldursson and von der Fehr, 2004).

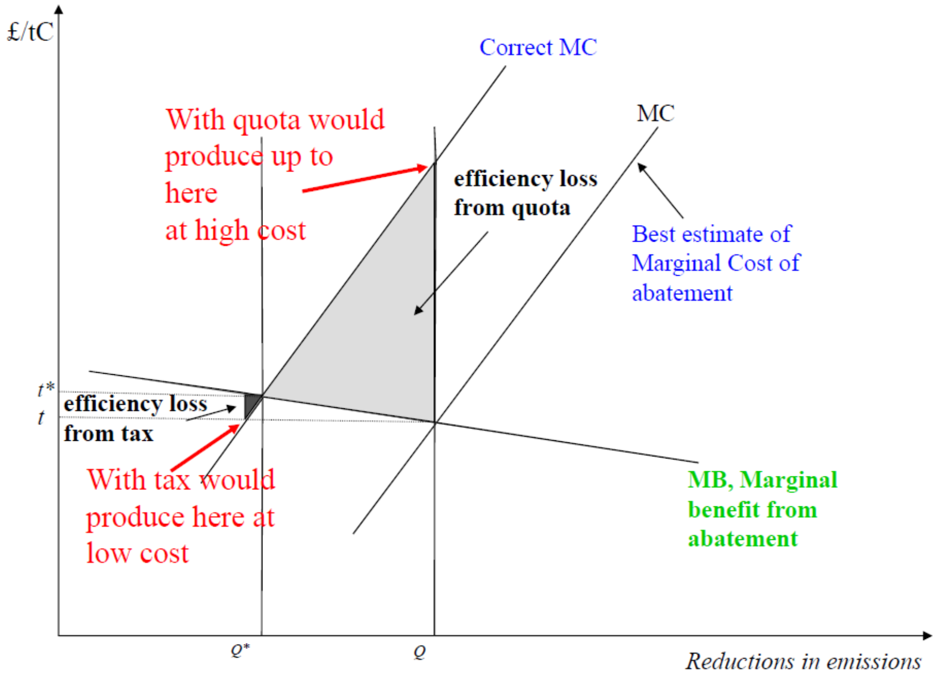

Figure 2. Efficiency loss under uncertainty of a carbon tax relative to a carbon quota

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 corridor" or "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 an *existing* ETS policy framework (rather than requiring a full transition to a carbon tax).

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.

6. Political economy 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 ensures that cross-border trade within the Integrated Electricity Market (IEM) is not distorted by unequal carbon prices.[19] 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, maintain and retire. The short-run impact on variable cost is stronger for plant with higher carbon intensities. Hence it alters the merit order of plant, leading to substitution to less carbon-intensive plant, and thus immediately reducing emissions as shown for Great Britain in Figure 1.

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 fluctuated between €5–10/tCO_2 from 2011-2017, far 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" (Newbery, 2016). 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).

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 investment 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), and (6) some abatement cost inefficiency due to unequal carbon prices in the EU electricity sector relative to other emissions-intensive industries subject to the EU ETS.[20]

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 baseload or mid-merit operation of existing coal and

[19] Although cross-border electricity trade across Europe 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 interconnectors to the EU 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.

[20] See also ICAP (2018) for a recent analysis of the interaction between carbon prices and electricity prices in the context of the EU ETS.

lignite power stations. 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.[21] This price floor could then rise at 3–5% annually above the rate of inflation to converge on the desired medium-run level. Starting now, this would yield a CPF, in real terms, of around €30–40/tCO_2 by 2025 and €35–55/tCO_2 by 2030. The proposed rate of increase is in line with the learnings from international CPF experience, as discussed in Sections 3 and 4. It is also consistent with the theoretical notion that the carbon price should rise over time at least at the social discount rate; this helps discourage incentives for inefficient delay of low-carbon investments.[22] Moreover, even if natural gas prices were to rise again, a commitment to this rate of increase until 2030 would likely encourage Large Electricity Producers (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 direct 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).[23]

A CPF that applies only to the power sector 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

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[21] This price for coal-to-gas switching is broadly in line with 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 that induces coal-to-gas switching is sensitive to coal and gas prices (Newbery, 2018a); a €1/MWh_{th} fall in the gas price, all else equal, requires a carbon price rise of around €5/tCO_2 to maintain its carbon-inclusive cost.

[22] The SCC measures the present social cost of future climate-related damages—for which the *social* discount rate is the appropriate discount factor. Given bankruptcy and other financial and reputational risks, private investors likely have a higher risk-adjusted discount rate—and may also have a socially excessive preference for plant with lower capital costs but higher emissions. This provides a further argument for a strong and durable carbon price pathway that alleviates uncertainty over future climate costs, rising annually *at least* at the social discount rate and arguably closer to the discount rate used by private investors. Our proposed 3–5% rate of increase seems in line with these arguments as well as international policy experience to date.

[23] A referee suggests thinking about coal-to-gas switching in terms of a target-consistent carbon price that also resolves the "missing money" underinvestment problem (Joskow, 2008). Specifically, a large-scale electricity-market model can be used to estimate the generation mix that delivers deep decarbonization (e.g. Williams et al. (2012)). Under current "business-as-usual" carbon prices, there is "missing money" for all generators that are needed to produce under this pathway but for which the wholesale market price is insufficient to cover their long-run marginal cost. The final step is to calculate the top-ups to carbon prices that deliver the desired pathway. While a quantitative analysis is beyond the scope of the current paper, it is certainly an interesting avenue for future research. We conjecture that these target-consistent carbon prices will typically be high enough to ensure substantial switching away from coal-fired generation, even over a relatively short time horizon. (As noted above, this comes with the caveat that the required carbon price is sensitive to prevailing fuel prices.)

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.[24]

We suggest implementation of the CPF as a carbon levy on fuels used by power generators so as to "top up" the prevailing EU ETS price to the desired level. This is in line with the existing CPS mechanism for electricity generation in Great Britain as well as the recent Dutch CPF proposal. Moreover, although periodic adjustments to the carbon levy are required, this design would not necessitate any change to the existing institutional arrangements of the EU ETS. Such an EU-wide CPF should, from 2019, also be compatible with the EU ETS's new Market Stability Reserve (MSR). 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. We believe that this is the simplest and most straightforward route to implement an EU-wide CPF that applies only to the power sector.[25]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 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.

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

[24] This argument is weakened somewhat in that electricity is used as an input to production in traded sectors. Moreover, sectoral differentiation of the carbon price already exists, to some extent, 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.

[25] A referee notes an alternative implementation of an EU power-only CPF via auction reserve prices. This would require the creation of a separate type of emissions allowance specifically for electricity generators (an 'EUEA'); without this separation from other ETS sectors, due to price arbitrage, it would not otherwise be possible to sustain two different carbon price signals. These EUEAs would then be periodically auctioned to European power companies with a price floor set at the maximum of the CPF and the EUA price. On one hand, the separation of electricity-sector allowances from the rest of the EU ETS would remove some current problems of allowance surplus as well as the waterbed-related interaction with the MSR. On the other hand, this mechanism would entail significantly larger institutional changes to the EU's existing climate policy than our top-up carbon levy. The creation of two separate EUA classes would likely also reduce trading liquidity in the carbon market. See Fischer et al. (2018) for a recent discussion of auction reserve prices that cover all EU ETS sectors.

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.[26]

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.

7. Political economy 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 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

[26] 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).

carbon intensity falling to 50gm/kWh by 2030, with no new coal plant built and renewables replacing gas generation (although gas capacity is still needed to manage periods with low output from intermittent renewable generation).[27] 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.

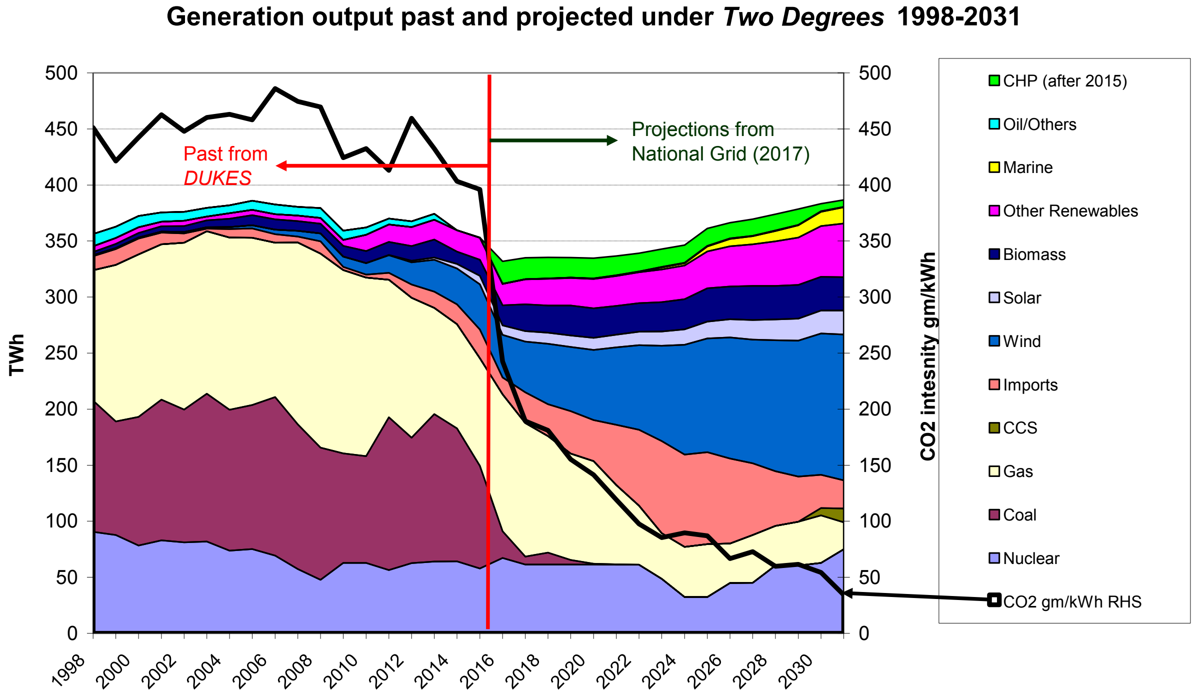

Figure 3. Historical and projected fuel mix in UK electricity generation under "Two Degrees" scenario
Source: National Grid (2017), *Future Energy Scenarios*

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* (previously 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/tCO_2, rising at 3–5% annually above inflation, at least up to 2030.[28] The domestic impacts of such a national

[27] See Newbery (2018b) for analysis of a wider range of flexibility options, including the small but growing role of storage.
[28] The case for a "top up" carbon levy is stronger for a national CPF relative to the EU-wide CPF discussed in the previous section. The alternative implementation via auction reserve prices now

CPF on the power sector are likely to be qualitatively 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 investment and innovation, with less financial support needed; (4) lower carbon emissions from the power sector; and (5) additional tax revenue.

Yet 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.[29] 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 whether a border tax adjustment on electricity imports from non-CPF jurisdictions is put in place.

In practice, there is likely to be some country-specific variation in the preferred level of a national CPF. Preferences will be driven by each country's overall decarbonization ambition and by how the cost of more or less rapid decarbonization of power compares to other sectors. In particular, the scope for coal-to-gas switching varies across countries, given differences in the existing fossil fuel generation mix (e.g., the relative efficiency and capacity levels of coal and gas plants) and in local fuel prices, notably the price of lignite. On one hand, a country with cheaper coal requires a higher CPF to induce switching to gas; on the other hand, such a country may have a stronger coal lobby—and hence political constraints—which pushes against a higher CPF. However, we suggest that for countries with serious longer-term climate targets, a national CPF may be an attractive policy instrument.

A lesson from the British experience, as discussed in Section 3, is that a national CPF may suffer from the problems of credibility of any fiscal instrument introduced by a single country. In contrast to the UK's five-year carbon budgets, the CPF's original price trajectory was never enshrined in law—and was then halted just as it began to rise, without any commitment to keeping the CPS beyond 2021. Indeed, since the CPS was frozen, the British government has repeatedly claimed it would offer a longer-term signal and then backed away (HoC Library, 2018). 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 in the 2013 *Energy Act* by an emissions performance standard (EPS) that ruled out new coal generation. At the

becomes increasingly complex: not only would allowances for the electricity sector have to be separated from other ETS sectors, a national CPF would also require that country's electricity allowances to become detached from the rest of the EU. Trading liquidity and price discovery in such a single-country, single-sector allowance auction may be significantly reduced.

[29] 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.

same time, the UK continued to maintain (and even expand) a diverse arsenal of shorter-term climate policy instruments, many of which were directed at other market failures or behavioural biases. Subsequently, the Government announced that coal generation would be phased out by 2025 (BEIS, 2018).

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 setting up the *Powering Past Coal* consortium, that now includes over twenty countries, 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). Like Britain, such jurisdictions can set an EPS, which, together with an CPF, effectively requires elimination of coal or the use of CCS (carbon capture and storage).

Why is a CPF (perhaps combined with an EPS) preferable to directly specifying a declining quantity trajectory for coal-fired generation? First, relying on a price instrument comes with the well-known flexibility benefits of a market signal; this may manifest itself, for example, during an unexpectedly harsh winter when access to coal-fired generation may temporarily become much more valuable. Second, unlike a coal phase-out, the carbon price has the attraction of also giving direct incentives to other low-carbon technologies and flexibility sources such as renewables and battery storage.[30] A national CPF for the power sector would lead to a similar waterbed effect to the EU CPF discussed in the previous section. For the benchmark case with a fixed and binding ETS cap, the waterbed is 100%.[31] Under the new MSR, it is expected to be 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. 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).[32]

Ideally the design of a national CPF should fully offset the waterbed effect—and aim to have a neutral impact on the EUA price. This point is recognized in the 2017-21 Dutch Coalition Agreement which argues that "the group of leading countries will need to introduce supplementary policy, for instance on buying up ETS emission allowances."[33] Indeed, the supplemental policy of buybacks and additional cancellation of national allowances is

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[30] 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 low-carbon generation over natural gas.

[31] If the ETS cap 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.

[32] The "pre-MSR" critique of the EU ETS is well-described by Edenhofer et al. (2017): "[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".

[33] 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).

explicitly allowed under the latest EU ETS reforms. The Government would first have to estimate the number of EUAs reduced by the domestic CPF.[34] 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).

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 GB 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.[35]

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.

8. Conclusions and policy implications

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 continue, officially at least, 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

[34] 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.

[35] 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.

whether or not other reforms gain pace. Combining it with a price ceiling—to create a price corridor—might make the policy more attractive to countries concerned about volatile 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, substantially alleviate the "waterbed effect" associated with such additional policies 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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