Avoid history repeating: The case for an EU ETS price floor revisited

Christian Flachsland[a,b], Michael Pahle[c], Dallas Burtraw[d], Ottmar Edenhofer[a,c,e], Milan Elkerbout[f], Carolyn Fischer[g,d], Oliver Tietjen[c], Lars Zetterberg[h]

[a] Mercator Research Institute on Global Commons and Climate Change (MCC), Berlin, Germany; [b] Hertie School of Governance, Berlin, Germany; [c] Potsdam Institute for Climate Impact Research (PIK), Potsdam, Germany; [d] Resources for the Future, Washington DC, USA; [e] Technical University Berlin, Germany; [f] Centre for European Policy Studies (CEPS), Brussels, Belgium; [g] Vrije Universiteit Amsterdam, The Netherlands; [h] Svenska Miljöinstitut IVL, Stockholm, Sweden.

Abstract [250 words]

Several years of very low allowance prices in the EU ETS have motivated calls for introducing a price floor to correct potential underlying distortions and design flaws, including (i) the political nature of allowance supply and related credibility issues, (ii) potential myopia of market participants and firms, and (iii) waterbed and rebound effects. In the wake of the recent EU ETS reform, EUA prices have sharply increased. This raises the question whether the case for a price floor in the EU ETS remains valid. We argue that such a price floor, also adopted in several other greenhouse gas cap-and-trade systems worldwide, remains an important improvement in the design of the system as long as the above-mentioned distortions and design flaws may prevail. An EU ETS price floor can safeguard against these issues and provides more explicit guidance on the minimum EUA price policymakers consider acceptable than the current Market Stability Reserve (MSR) design. We identify and confront four prominent arguments against the introduction of an EU ETS price floor.

Policy relevance [3-5 bullet points, appr. 100 words]

- An EU ETS price floor would be an important institutional innovation enhancing the political and economic stability and predictability of the EUA price
- The recent MSR reform has not removed the need for a carbon floor price
- Introducing an element of price responsiveness into the so far purely quantitative design of the EU ETS design would help to preserve its integrity
- In contrast to conventional wisdom, legal analysis reveals that an EU ETS price floor can be legally feasible
- Political support for a carbon floor price is getting traction across Europe

Keywords: EU ETS, Price Floor, Market Stability Reserve

1. Introduction

The EU ETS has for many years delivered prices below initial expectations. If low prices merely indicate low mitigation costs, they indicate that the scheme works as theory suggests (Ellerman et al. 2016). However, the concern was raised that low prices reflected market distortions and design flaws (Edenhofer et al. 2017). These include (i) the political nature of allowance supply and related credibility issues, (ii) myopia or inefficient discounting of market participants and firms, and (iii) waterbed and rebound effects from unilateral emission reductions. The potential presence of these issues implies the risk of negative long-term consequences by failing to initiate and support the technological and economic transformations necessary to decarbonize the economy (Acworth et al. 2017, Fuss et al. 2018). Allowance prices in cap-and-trade are subject to large uncertainty (Borenstein et al. 2018) and market distortions may lead to inefficiency if opportunities for hedging through risk markets is limited (Tietjen et al. 2019).

To address these concerns, adding a carbon price floor to the EU ETS following the examples e.g. of the Regional Greenhouse Gas Initiative, the common ETS of California and Quebec, and some Chinese pilot ETS has been proposed (Knopf et al. 2014, Boehringer and Fischer 2018, ICAP 2019). However, the sharp increase of European Emission Allowances (EUA) prices in 2018 to levels around 20-25€/t (May 2019) places the EUA price at the magnitude found in economic optimization models (e.g., Pahle et al. 2018a). The recent ETS reform has increased the Linear Reduction Factor determining the annual rate of decline of the cap, and has modified the market stability reserve (MSR) to increase the rate of annual allowance removals and invalidate (cancel) many allowances. While it remains challenging to empirically assess the optimal level of allowance prices in cap-and-trade systems (Hintermann et al. 2016), the reform seems to have successfully addressed the broader concern over low prices. This raises the question whether the case for a price floor in the ETS remains valid, which ultimately depends on the problem diagnosis.

We argue that a price floor remains an important improvement in the design of the ETS if there is no certainty about the existence of the above-mentioned distortions and regulatory failures that might prevent dynamically efficient price formation. The potential existence of these issues implies the risk of a dynamically inefficient EUA price path (e.g. Salant 2016, Fuss et al. 2018). A price floor can reduce this risk, and provides more explicit guidance on the minimum EUA price policymakers consider acceptable than the current MSR design. It would thus be less prone to future revision in case of unexpectedly low prices.

2. Methods

Our contribution builds on two methods. First, we conducted a comprehensive review of the academic and policy literature on greenhouse gas (GHG) cap-and-trade system price floors and their adoption in existing systems worldwide, and on the recent EU ETS reform. Second, over the past years the authors organized and participated in several workshops in which academic analyses and policy questions relating to the introduction of a price floor were explicitly discussed with high-level stakeholders from academia, policy (EU and national institutions), industry, and NGOs. The author team jointly organized a workshop “EU ETS Reform: Taking Stock and Examining Carbon Price Floor Options” in Brussels on 3 July 2018. Building on the conversation in this and other workshops[1], l conversations with key policymakers and stakeholders, and close monitoring of the policy debate over the recent years, and extensive discussions within the author team, we distilled a set of four objections to a price floor to which we respond below.

3. The recent EU ETS reform: Mainstream diagnosis and therapy

Different reasons for low EUA prices in past years have been suggested, not least because understanding of the drivers of EUA price let alone their level remains poor (Hintermann et al. 2016, Friedrich et al. 2019). The mainstream view has been that the key reason for prices being lower than expected is an "imbalance" of allowance supply and demand. This is thought to result from the economic crisis, the influx of credits under the Clean Development Mechanism, rigid free allocation based on historical output levels, and additional renewable and energy efficiency policies at the EU and member state levels (Koch et al. 2014, Fuss et al. 2018, Ellerman et al. 2016). This view has been guiding the recent EU ETS reform that intended to "reduce the surplus of emissions allowances […] and to improve the EU ETS's resilience to shocks" (EC 2019).

In consequence, the recent reform primarily aimed at creating additional scarcity in the market. This is achieved, first, by strengthening of the linear reduction factor, specifying the amount that the cap will be reduced annually, from 1.74 to 2.2 percent. Second, the rate at which the MSR diverts allowances from auctions when the stock of allowances in circulation exceeds 833 million EUAs was doubled from 12% to 24% for the period 2019 until 2023. Third, all allowances in the MSR exceeding the level of the previous year's volume of auctioned allowances will be invalidated from 2023 on. Fourth, unilateral invalidation of allowances by member states in proportion to national regulations closing down facilities, e.g. coal plants, covered by the EU ETS is now allowed.

The reform will reduce allowance supply, thus addressing concerns about supply-demand imbalances. Estimates regarding the amount of allowances moved to the MSR and invalidation of allowances vary significantly (Beck & Kruse-Andersen 2018, Bocklet et al. 2019, Bruninx et al. 2018, Burtraw et al. 2018, Carlén et al. 2019, Danish Council on Climate Change 2017, Quemin and Trotignon 2019, Perino 2018, Perino and Willner 2017, Sandbag 2017, Silbye & Sørensen 2018). For example, Beck & Kruse-Andersen (2018) find that 6 Gt will be invalidated, in contrast to 1.7 Gt in Perino and Willner (2017).

During the debate and especially after the reform was decided the EUA price has risen discernibly. According to standard economic theory, the most likely explanation is that anticipated future scarcity of allowances—reducing supply—resulted in increased current prices (Perino and Willner 2017). Other work suggests that transferring allowances into the MSR creates transitional stringency sufficient to raise prices at least in the short-term (Mauer et al. 2019), especially if the hedging demand of firms for allowances is considered (Tietjen et al. 2019). A complementary interpretation is that the reform has restored market confidence in the willingness of EU policymakers to invest political capital into sustaining the ETS, triggering the comeback of allowance traders taking longer-term positions in the market (Sheppard 2018; Tagesspiegel 2018). A third interpretation is that price formation is myopically driven by short-term demand and supply and that the increased intake rates of the MSR leads to a tighter short-term market, inducing an EUA price increase.

It is uncertain, though, whether the fundamental problems of the EU ETS have been resolved for good. First, there is no solid evidence for what has driven the recent price increase. It might well be a bubble in an overconfident market (Friedrich et al. 2019). Second, there is a persistent risk that market confidence may be undermined again by future economic or political shocks. Given the complexity of the MSR, market actors may misjudge future effects, and unexpected outcomes may require further market interventions, possibly affecting market confidence. Finally, the waterbed has not been effectively removed by the recent reform (see below) and might lead to lowered allowance prices. Overall, we cannot rule out that history will repeat itself and EUA prices will drop again – with potentially significant consequences for the legitimacy and political support of the policy instrument.

4. The case for an EU ETS price floor and implementation options

Theoretical analysis suggests that anticipated future downward price shocks or persistent doubt about the level of ambition work towards decreasing current prices (Salant 2016). Evidence suggests that past regulatory events, such as the backloading reform episode, have indeed negatively affected market credibility and triggered a price decrease (Koch et al. 2016). Reduced market confidence and low prices arguably reinforce unilateral member states' efforts to introduce additional policies to attain national climate targets, which may further drive down prices in a negative spiral due to the waterbed effect (Pahle et al. 2018a). Inefficient discounting for example due to Myopia or incomplete risk markets might also dampen near-term allowance prices (Kollenberg and Taschini 2016; Holt and Shobe 2016; Fuss et al. 2018; Quemin and Trotignon 2019; Tietjen et al. 2019; Willner 2018). If these were indeed the underlying problems, the recent reform then may just have cured the symptoms, but not necessarily their underlying root problems.

A price floor has the following advantages: It would enhance long-term investment certainty by providing a clearer signal of regulators' commitment to achieve ambitious decarbonization targets (Wood and Jotzo 2009, Burtraw et al. 2010). Price floors may also help avoid myopic price formation if they align the carbon price trajectory more closely with the efficient level and rate of increase. Price floors implemented at modest levels lock in current levels of ambition and enable ratcheting up over time when they automatically increase at a specified rate. While it is correct that price floors may be politically revised (downwards or upwards), and thus do not offer a perfect commitment device, we argue that policy stability and credibility is at least gradually increased, thus improving investment incentives. This important benefit comes at no cost in terms of reduced system performance. The main cost appears to be political capital expended to initiate and implement the reform.

A price floor can be implemented in the following ways: The ETS of California and Quebec, the Regional Greenhouse Gas initiative (RGGI) and several Chinese provincial ETS pilots have implemented a price floor as an auction reserve price(s)below which none or only a fraction of allowances will be sold (ICAP 2019). In the EU ETS, an EU-wide auction reserve price might be introduced in addition to the arbitrary quantity threshold level of 833 megaton (Mt) allowances in circulation in the MSR. Unsold allowances could be moved into the MSR, where they might eventually be invalidated.

A second potential price floor implementation option is the UK carbon price floor (CPF), which requires power sector facilities covered by the EU ETS to pay a carbon price support that scales with expected EUA prices to ensure that a specific domestic minimum carbon price is always achieved (Hirst 2018). Currently, the support is set at £18/t (~€20) until 2021, adding to a EUA price of about €20–€25/t. To make the support rate more responsive to the actual EUA price realization than in the UK design, an ex post adjustment based on the average realized EUA price is an alternative implementation option (Wood and Jotzo 2009).

5. Debating the price floor option

In discussions with various stakeholders (see Methods) we identified four prominent arguments against the introduction of an EU ETS price floor, which we confront below.

5.1 Objection #1: The MSR reform removes the need for a price floor

Objection: The recent price increase demonstrates that the fundamental problems of the EU ETS have been addressed. The allowance removal and invalidation features of the MSR reform eliminate the waterbed effect and reestablish fundamental allowance scarcity. The policy environment for low-carbon investments is now stable and predictable.

Response: The causality and durability of the EUA price increase is not yet determined. We cannot know whether the reform and economic circumstances will sustain high price levels**.** Market participants might misconceive the actual impact of the complex MSR invalidation mechanism. Credibility issues might easily return in case of political and economic shocks.

The reform has partially addressed the waterbed effect of unilateral policies, but not eliminated it. The MSR cancellation depends on the time profile of the specific measure and immediate waterbed and rebound effects (Pahle et al. 2019, Perino et al. 2019). Unilateral policies only reduce emissions if they *increase* the allowances bank (TNAC) *before* the allowance influx into the MSR stops (i.e. TNAC > 833 Mt must hold), because this implies invalidations via the MSR. However, aggregate emission reductions from unilateral measures are not guaranteed. For example, reducing emissions in Germany with a coal power plant phase-out (and without proportionally cancelling allowances) will lead to an increase in the power price, making coal power production at unregulated plants in Germany and interconnected power markets more attractive (rebound effect, Osorio et al. 2018). In addition, reduced demand for allowances dampens the EUA price path, making additional emissions profitable across Europe (waterbed effect). If the increase of emissions due to the rebound and waterbed effect combined is larger than the decrease of emissions in the German power sector, the coal phase-out could *reduce* the allowances bank. If this happens *before* the allowance influx into the MSR stops, less MSR invalidation takes place and thus the coal phase-out could increase overall emissions (Pahle et al. 2019). Unilateral policies that are announced today but effective in the far future can lead to more overall emissions via this mechanism. Similarly, Burtraw and Keyes (2018) find that unilateral policy to reduce emissions in 2018 would cause about 88 percent of the marginal additional allowances in circulation to be permanently invalidated by 2030. The later mitigation occurs, the fewer allowances will be cancelled and the higher will be the waterbed effect.

If an auction reserve price binds, then unilateral emission reductions would lead to withholding allowances from auctions, which might be invalidated. When using the UK institutional design, to tackle the waterbed effect an additional allowance invalidation mechanism would be required.

5.2 Objection #2: A price floor would transform the EU ETS from a quantitative policy instrument into a pricing instrument

Objection: Much effort has been invested in establishing the ETS as a quantitative policy instrument. This regulatory approach has ensured broad support from member states, industry, and EU institutions because it guarantees the climate target is reached.

Response: The quantity target is not arguably optimal; rather it is the consequence of a scientifically informed regulatory negotiation. If emissions reductions turn out to be less expensive than anticipated then regulators would compel greater emissions reductions, and the price floor embodies such instruction to the market (Wood and Jotzo 2019). Price floors have been widely adopted in quantity-based ETSs worldwide, and for good reason (ICAP 2019). In fact, the EU ETS is increasingly becoming a special case in that it does not feature quantity adjustment based on rule-based price triggers. Furthermore, introducing a price floor does not imply the instrument is not based on quantity controls;if unsold allowances are invalidated, a price floor would enable achieving *more*

ambitious environmental targets than those envisioned by the baseline cap.[2] From economic theory, a hybrid instrument that combines elements of quantity and price regulation is likely to be superior to either approach taken alone for regulating carbon emissions under uncertainty (e.g., Weitzman 1974; Roberts and Spence 1976; Newell and Pizer 2003; Hepburn 2006; Wood and Jotzo 2009).

5.3 Objection #3: A carbon price floor is not legally feasible

Objection: A carbon tax could not be introduced in the 1990s because of the EU Council unanimity requirement of EU treaties on tax matters. This legal requirement would also make an EU ETS price floor infeasible.

Response: Fischer et al. (2019) reject the claim that introducing an auction reserve price into the EU ETS could not proceed with the ordinary legislative procedure. To trigger the special (unanimous voting) rather than ordinary (qualified majority voting) legislative procedure, a reserve price would have to be "primarily of a fiscal nature" or "significantly affect a Member State's choice between different energy sources." The first trigger ("primarily of a fiscal nature"), although not well defined in EU law, should not apply for three reasons: First, the primary aim of the EU ETS is to reduce emissions, not to raise government revenue. Much of the allowance revenue is either freely allocated (negating the revenue motive) or earmarked for mitigation programs (as with a fee), but not collected for general revenues (as with a tax). Furthermore, an auction reserve price may lower or raise revenues, since the prices may rise but the number of allowances sold falls. Second, EU allowances have the status of financial instruments, and the ETS thus has already been shown not to be of fiscal nature. Third, an auction reserve price would not change the character or strictly fix the EUA price. Allowances could trade above or below that level in the secondary market, as has been the case in the California system.

Fischer et al. (2019) also reject the argument that an ETS auction reserve price might "significantly affect a Member State's choice between different energy sources." First, an allowance price does not directly determine the energy mix of member states. Instead, its effects depend on the broader market situation (e.g., fuel prices). A legal trigger for the treaty unanimity requirement should not depend on market circumstances. Second, the EU ETS embodies an important environmental goal in justifying the competence of the European Union to introduce a cap-and-trade system establishing an EU-wide carbon price, and an incremental reform supporting the system would rely on the same competence. The European Court of Justice rejected a recent challenge by Poland to the initial version of the MSR based on this legal trigger, finding that market circumstances remain essential for the choice of energy sources and that the EU ETS constitutes a justified environmental policy.

5.4 Objection #4: Finding agreement on a common floor price will be impossible, and unilateral carbon price floors would fragment EU climate policy

Objection: Reluctant member states will strongly oppose a price floor above current or expected prices, since that effectively increases the level of ambition of the ETS. If the price floor is set at a lower level than the current price, it is irrelevant. If agreement on a common floor cannot be achieved, a unilateral price floor implemented by one member state or a coalition of member states will reinforce political fragmentation, divergence and inefficiency in decarbonization pathways across Europe.

Response: For a few years France was the only EU member state openly advancing the idea of a price floor (Szabo 2016). Like the UK CPF, the French initiative envisioned a price floor only for the power sector.[3] More recently, supportive signals have also come from the Netherlands (ICAP 2017), Sweden

(Stam 2018), and Portugal and Spain (Brnic and Thévoz 2018). German discussions about the carbon price floor option have intensified (e.g., Edenhofer et al. 2017; Hecking et al. 2017; Fernahl et al. 2017; Matthes et al. 2018; Demirdag 2018). Stakeholders likely to benefit from higher EUA prices (e.g., nuclear, gas and renewable power generators) can be expected to support this option.

Setting a price floor below the prevailing level of the carbon price should facilitate adoption. The goal of the price floor would be, first, to provide insurance against the risk of price drops that threaten low-carbon investments. Second, it would lock in the current level of ambition and enable ratcheting up over time (Pahle et al. 2018a, b). The price floor can help achieve this outcome by automatically increasing at a specified rate, such as the opportunity cost of capital plus inflation. For example, the California ETS price floor increases at 5 percent plus inflation, and RGGI envisions a 7 percent annual increase of its Emissions Containment Reserve trigger price after it is introduced in 2021, independent of inflation (ICAP 2019).

A harmonized EU-wide approach would be clearly preferable to avoid political fragmentation. If an EU-wide approach is not politically feasible, there may be reasons for a coalition to act as a first mover, initiating a policy sequence (Pahle et al. 2018a) that will eventually lead to the remaining EU states joining. This strategy would be in line with considerations of shifting toward a Europe where "those who want more do more" to overcome political impasse (European Commission 2017).

6. Conclusion: The way forward

An EU ETS price floor to be adopted by *all* member states could be advanced in the context of various policy processes:

- **2021**: **MSR review**. The review could be used to initiate the process for formally assessing and proposing price floor legislation, with a subsequent legislative process to be finished around 2023. For example, an EU-wide auction reserve price could be considered that would adjust the MSR such that the trigger for removal of allowances from primary auctions would be an EUA primary auction reserve price rather than, or potentially in addition to, the arbitrary quantity threshold level of 833 Mt allowances in circulation.
- **2023: Paris Agreement stock-take.** This effort could be used to initiate a process for formally assessing and proposing price floor legislation, with a subsequent legislative process to be finished around 2025.

In parallel to an EU-wide price floor, a bottom-up *coalition of a few* countries would have more flexibility in the timing of their action. An agreement between Germany and France would arguably be essential to advance such a coalition. The Netherlands, for example, are currently exploring legislation to implement a unilateral floor price. This coalition could grow and eventually create sufficient support for an EU-wide price floor.

Notes

1. A series of five workshops with high-level EU ETS German stakeholders discussing EU ETS price floor options and related topics was held at the MCC in Berlin 2017. Another workshop on "Emissions Trading: Which way forward," held on 28 March 2019 in Paris, was organized by several of the authors, convening academic researchers and stakeholders from industry and national governments to discuss the recent EU ETS reform and related analyses, including the option of a price floor. In May 2017 a workshop was organized in Gothenburg to identify and discuss legal aspects of introducing a price floor. In addition, all of the authors

participated as speakers and discussants in numerous EU ETS-related workshops and policy advice activities over the recent years.

2. We do not consider the case of a price ceiling that would trigger the release of additional allowances, which might lead to non-achievement of the original quantitative target.

3. Some note that because the French electricity mix is heavily based on nuclear power, it would benefit from an increasing carbon price (Hecking et al. 2017; Pahle et al. 2018a).

Declaration of interest

No potential conflict of interest was reported by the authors.

Acknowledgements

The authors would like to particularly thank participants at the workshop "EU ETS Reform: Taking Stock and Examining Carbon Price Floor Options", held at the Centre for European Policy Studies (CEPS) in Brussels on July 3, 2018, for a very helpful discussion of EU ETS carbon price floor options. Contributions to this paper were sponsored by the AHEAD and Mistra Carbon Exit projects.

References

Acworth, W., Ackva, J., Burtraw, D., Edenhofer, O., Fuss, S., Flachsland, C., Haug, C., Koch, N., Kornek, U., Knopf, B. and Montes de Oca, M. 2017. "Emissions Trading and the Role of a Long Run Carbon Price Signal: Achieving cost effective emission reductions under an Emissions Trading System." Berlin: ICAP.

Agora Energiewende und Öko-Institut. 2018. Vom Wasserbett zur Badewanne. Die Auswirkungen der EU-Emissionshandelsreform 2018 auf CO_2-Preis, Kohleausstieg und den Ausbau der Erneuerbaren.

Beck, U., Kruse-Andersen, P.. 2018. "Endogenizing the cap in a cap-and-trade system: Assessing the agreement on EU ETS phase 4." Working Paper.

Bocklet, J., Hintermayer, M., Schmidt, L., Wildgrube, T., 2019. The Reformed EU ETS - Intertemporal Emission Trading with Restricted Banking. EWI Working Paper, No 19/04.

Boehringer, C., and C. Fischer. 2018. "Emissions Floor Price Options for EU Member States." University of Oldenburg and Vrije Universiteit Amsterdam.

Borenstein, S., J. Bushnell, F. Wolak, M. Zaragoza-Watkins. 2018. "Expecting the Unexpected: Emissions Uncertainty and Environmental Market Design." Haas Working Paper.

Brnic, A. H., and L. F. Thévoz. 2018. "EDF hopes for European CO_2 price floor within months." *Montel*, July 31. https://www.montelnews.com/en/story/edf-hopes-for-european-co2-price-floor-within-months/922209.

Bruninx, K., Ovaere, M., & Delarue, E., 2018. A First Analysis Of the Market Stability Reserve in the European Emission Trading System. TME Working Paper.

Burtraw, D., Palmer, K., & Kahn, D. (2010). A symmetric safety valve. *Energy Policy* 38(9): 4921–4932.

Burtraw, D., A. Keyes. 2018. “European Union Reforms Its Carbon Emissions Market” *Resources Magazine* 7.10.18, https://www.resourcesmag.org/archives/european-union-reforms-its-carbon-emissions-market/.

Burtraw, D., A. Keyes, and L. Zetterberg. 2018. “Companion Policies under Capped Systems and Implications for Efficiency – The North American Experience and Lessons in the EU Context.” RFF Working Paper. http://www.rff.org/research/publications/companion-policies-under-capped-systems-and-implications-efficiency-north.

Carlén, B., Dahlqvist, A., Mandell, S. & Marklund, P., 2019. EU ETS emissions under the cancellation mechanism - Effects of national measures. Energy Policy 129: 816–825.

Cullenward, D., and A. Coghlan. 2016. “Structural oversupply and credibility in California’s carbon market.” *Electricity Journal* 29: 7–14.

Danish Council on Climate Change, 2017. The Inflated EU Emissions Trading System. Consequences of the EU ETS and Surplus of Allowances for Danish Climate Policy.

Demirdag, J. 2018. “Eleven German state ministers urge CO_2 price floor.” *Montel*, July 16. https://www.montelnews.com/en/story/eleven-german-state-ministers-urge-co2-price-floor-/918136.

EC – European Commission. 2019. “EU ETS Revision for Phase 4 (2021-2030).” Website information available at https://ec.europa.eu/clima/policies/ets/revision, Accessed 9 May 2019.

Edenhofer, O., C. Flachsland, C. Wolff, L. K. Schmid, A. Leipprand, N. Koch, U. Kornek, and M. Pahle. 2017. “Decarbonization and EU ETS Reform: Introducing a price floor to drive low-carbon investments.” Policy Paper. https://www.mcc-berlin.net/fileadmin/data/C18_MCC_Publications/Decarbonization_EU_ETS_Reform_Policy_Paper.pdf.

EEA (European Environment Agency). 2017. “Trends and Projections in the EU ETS in 2017: The EU Emissions Trading System in Numbers.” EEA Report No 18/2017. https://www.eea.europa.eu/publications/trends-and-projections-EU-ETS-2017.

Ellerman, D., C. Marcantonini, A. Zaklan. 2016. “The European Union Emissions Trading System: Ten Years and Counting.” *Review of Environmental Economics and Policy* 10 (1): 89–107.

EU. 2018. Directive (EU) 2018/410 of the European Parliament and of the Council of 14 March 2018 Amending Directive 2003/87/EC to Enhance Cost-Effective Emission Reductions and Low-Carbon Investments, and Decision (EU) 2015/1814. http://data.europa.eu/eli/dir/2018/410/oj.

European Commission. 2017. *White Paper on the Future of Europe. Reflections and Scenarios for the EU27 by 2025*. European Commission COM (2017) 2025. March 1. https://ec.europa.eu/commission/sites/beta-political/files/white_paper_on_the_future_of_europe_en.pdf.

Fernahl, A., C. Perez-Linkenheil, F. Huneke, and I. Küchle. 2017. *Wirkungsweise einer CO_2-Steuer im Stromsektor*. Berlin: Energy Brainpool.

Fischer, C., L. Reins, D. Burtraw, D. Langlet, M. Mehling, S. Weishaar, L. Zetterberg, H. van Asselt, K. Kulovesi, and A. Lofgren. 2018. „The Legal and Economic Case for an Auction Reserve Price in the EU Emissions Trading System.” Working paper, May 30.

Friedrich, M., Mauer, E.M., Pahle, M., Tietjen, O., 2019. From fundamentals to financial assets: the evolution of understanding price formation in the EU ETS. Working paper.

Fuss, S., C. Flachsland, N. Koch, U. Kornek, B. Knopf, and O. Edenhofer. 2018. "A Framework for Assessing the Performance of Cap-and-Trade Systems: Insights from the European Union Emissions Trading System." *Review of Environmental Economics and Policy* 12 (2): 220–41.

Hecking, H., J. Kruse, and F. Obermüller. 2017. "Analysis of an EU-Wide Carbon Price Support: Impact on CO_2 Emissions, Cost Efficiency and Rents." EWI Energy Research & Scenarios. https://www.ewi.research-scenarios.de/cms/wp-content/uploads/2017/01/Analysis-of-an-Euwide-Carbon-Price-Support.pdf.

Hepburn, C. 2006. "Regulation by prices, quantities, or both: a review of instrument choice. *Oxford Review of Economic Policy* 22 (2): 226–247.

Hintermann, B., S. Peterson, and W. Rickels. 2016. "Price and market behavior in Phase II of the EU ETS: A review of the literature." *Review of Environmental Economics and Policy* 10 (1): 108–28.

Hirst, D. 2018. "Carbon Price Floor (CPF) and the Price Support Mechanism." House of Commons Library Briefing Paper No. 05927. January 8. http://researchbriefings.files.parliament.uk/documents/SN05927/SN05927.pdf.

Holt, C.A., W.M. Shobe. 2016. "Price and quantity collars for stabilizing emission allowance prices: Laboratory experiments on the EU ETS market stability reserve." *Journal of Environmental Economics and Management* 80: 69-86.

ICAP (International Carbon Action Partnership). 2017. "Netherlands Proposes EUR 18 Carbon Price Floor." https://icapcarbonaction.com/fr/news-archive/491-netherlands-proposes-eur-18-carbon-price-floor.

———. 2019. "ETS Map." https://icapcarbonaction.com/en/ets-map.

Knopf, Brigitte, et al. 2014. "The European Emissions Trading System (EU ETS): ex-post analysis, the market stability reserve and options for a comprehensive reform." FEEM Nota di Lavoro Working Paper.

Koch, Nicolas, et al. 2014. "Causes of the EU ETS price drop: Recession, CDM, renewable policies or a bit of everything?—New evidence." *Energy Policy* 73: 676-685.

Koch, N., G. Grosjean, S. Fuss, and O. Edenhofer. 2016. "Politics matters: Regulatory events as catalysts for price formation under cap-and-trade." *Journal of Environmental Economics and Management* 8: 121–39.

Kollenberg, S., and L. Taschini. 2016. "Dynamic Supply Adjustment and Banking under Uncertainty: The Market Stability Reserve." Working paper, March 2. https://ssrn.com/abstract=2742256.

Matthes, F., et al. 2018. „Dem Ziel verpflichtet. CO_2-Mindestpreise im Instrumentenmix einer Kohle-Ausstiegsstrategie für Deutschland." https://www.oeko.de/aktuelles/2018/mindestpreis-auf-co2-fuer-mehr-klimaschutz/.

Mauer, E.M., S. Okullo, M. Pahle. 2019. „Evaluating the performance of the EU ETS MSR." Paper presented at the 2019 Mannheim Energy Conference.

Newell, R. G., and W.A. Pizer. 2003. "Regulating stock externalities under uncertainty." *Journal of Environmental Economics and Management* 45 (2):416–32.

Osorio, S., R. Pietzcker, M. Pahle., O. Edenhofer. 2018. How to Deal with the Risks of Phasing out Coal in Germany through National Carbon Pricing. CESifo Working Paper No. 7438.

Pahle, M., D. Burtraw, O. Tietjen, C. Flachsland, and O. Edenhofer. 2018a. "Preserving the Integrity of the EU ETS under Unilateral Action." Paper presented at World Congress for Environmental and Resource Economics, Gothenburg.

Pahle, M., D. Burtraw, C. Flachsland, N. Kelsey, E. Biber, J. Meckling, O. Edenhofer, and J. Zysman. 2018b. "Sequencing to ratchet up climate policy stringency." *Nature Climate Change* 8: 861–67.

Pahle, M., O. Edenhofer, R. Pietzcker, O. Tietjen, S. Osorio, C. Flachsland. 2019. „Die unterschätzten Risiken des Fahrplans für den Kohleausstieg". Working Paper.

Perino, G., M. Willner. 2017. "Allowance prices, design choices and the market stability reserve in Phase IV of the EU ETS." *Climate Policy* 17 (7): 936-946.

Perino, G. 2018. "New EU ETS Phase 4 rules temporarily puncture waterbed." *Nature Climate Change* 8: 262.

Perino, G., R.A. Ritz, A. van Benthem. 2019. "Understanding Overlapping Policies: Internal Carbon Leakage and the Punctured Waterbed." NBER Working Paper No. 25643.

Quemin, S., R. Trotignon. 2019. "Intertemporal Emissions Trading and Market Design: An Application to the EU-ETS". Working Paper.

Roberts, M. J., and M. Spence. 1976. "Effluent charges and licenses under uncertainty." *Journal of Public Economics* 5 (3–4): 193–208.

Salant, S. W. 2016. "What ails the European Union′ s emissions trading system?" *Journal of Environmental Economics and Management* 80: 6–19.

Sandbag 2017, An agenda for strategic reform of the ETS. What's the future for EU carbon pricing? Report.

Sheppard, D. 2018. "Hedge funds and Wall St banks cash in on carbon market's revival." *Financial Times*. September 6.

Silbye, F., Sørensen, P. B., 2018. Towards a more efficient European carbon market. Working Paper.

Stam, C. 2018. "Ministers highlight European divide over carbon price floor." *Euractiv*, April 18. https://www.euractiv.com/section/emissions-trading-scheme/news/ministers-highlight-european-divide-over-carbon-price-floor/.

Szabo, M. 2016. "'We can't wait any longer': France floats EU ETS price support proposal." *Carbon Pulse*, March 13. http://carbon-pulse.com/16939/.

Tagesspiegel. 2018. "CO_2-Preis sprengt alle Prognosen." Tagesspiegel background, September 12.

Tietjen, O., Lessmann, K., Pahle, M., 2019, Hedging and the Temporal Permit Issuance in Cap-and-Trade Programs. Working paper, available at https://www.pik-potsdam.de/members/otietjen/cat-hedging.pdf/at_download/file.

Weitzman, M. L. 1974. "Prices vs. quantities." *Review of Economic Studies* 41 (4): 477–91.

Willner, M. 2018. "Consulting the Chrystal Ball: Firms' Foresight and a Cap-and-Trade Scheme with Endogenous Supply Adjustments". Working Paper, available at https://ssrn.com/abstract=3231927.

Wood, Peter John, and Frank Jotzo. "Price floors for emissions trading." Energy Policy 39.3 (2011): 1746-1753.