



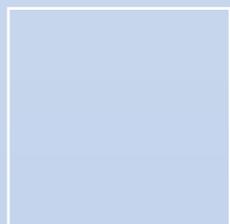
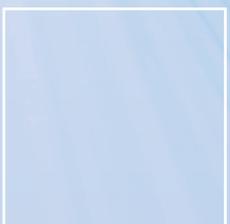
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POLICY

BRIEF



Low-carbon Innovation and Investment in the EU ETS

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Highlights

- The empirical literature indicates that, in Phases I and II, the impact of the EU ETS on low-carbon innovation was moderate. The findings of one prominent study, which measures innovation output by patent counts, present a more clearly positive picture.
- The empirical literature indicates that, in Phases I and II, low-carbon investments brought about by the EU ETS were typically small-scale, with short amortisation times (e.g., three to five years), producing incremental emission reductions.
- In view of the EU's long-term emission reduction targets, there is scope to improve the dynamic efficiency of the EU ETS by strengthening incentives for low-carbon innovation and investment. Tightening the cap and extending allowance auctioning in a predictable way are the most frequent recommendations in the literature.
- There is a compelling economic case, related to innovation spillovers, scale and network economies, competitiveness preservation and energy security, for complementing the EU ETS with stronger R&D policies.
- The Innovation Fund – the future EU ETS funding programme for low-carbon innovation – will build on the experiences gained through the existing NER 300 programme in several important respects.



1. Introduction

Since 2005, the EU Emissions Trading System (EU ETS) has been the main instrument adopted by the EU for decarbonising its economy and, globally-speaking, the largest cap-and-trade scheme. The EU ETS imposes a cap on total emissions of carbon dioxide, nitrous oxide and perfluorocarbons from more than 11,000 heavy energy-using and power-generating installations and airlines, covering about 45% of the EU's greenhouse gas (GHG) emissions.

As of Phase III (2013-2020), the EU ETS cap declines linearly over time, reaching in 2020 a level that is 21% below that of regulated emissions in 2005.¹ According to the revision for Phase IV (2021-2030) proposed by the European Commission (EC), the cap will then decline more rapidly, reaching in 2030 a level that is 43% below that of 2005 emissions (COM (2015) 337). The EU is also committed to reducing its overall GHG emissions by at least 80% by 2050. Crucially, continued progress in the invention, adoption and diffusion of low-carbon production processes and products will be necessary for meeting said targets and for minimising related costs. Following the economic crisis, however, the persistent imbalance between the supply and demand for allowances, and the corresponding impact on the carbon price signal, have led to concerns as to whether existing incentives are sufficient for spurring the necessary levels of innovation and diffusion of low-carbon technologies. Steps have been taken for addressing the surplus of allowances through the 'backloading' of 900 million allowances and, in a structural way, with the establishment of the Market Stability Reserve (MSR).² Additional measures for supporting low-

carbon innovation and investment are foreseen in the proposed revision for Phase IV.

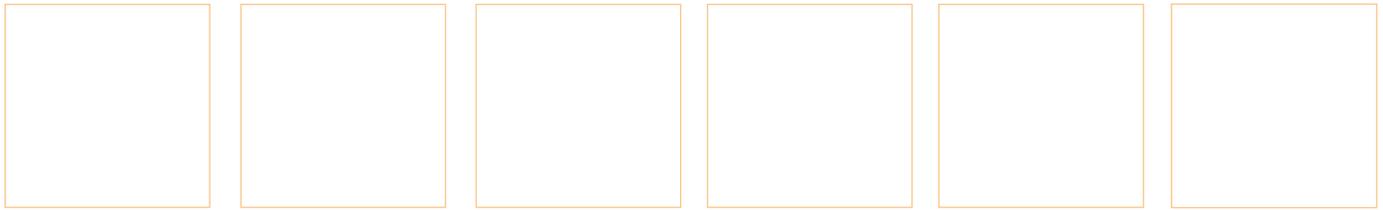
This policy brief draws on the assessment of the EU ETS that the Florence School of Regulation Climate (FSR Climate) is carrying out and on a related workshop on low-carbon innovation and investment. Both the assessment and the workshop are part of the LIFE SIDE project (www.lifesideproject.eu).³ The brief is organised as follows. Section 2 recalls the concepts of static and dynamic efficiency with reference to the EU ETS. Section 3 summarises the evidence for the impact of the EU ETS on low-carbon innovation and investment. Section 4 illustrates the EU ETS funding programmes for low-carbon innovation. Section 5 reports some points made in the workshop. Section 6 concludes the policy brief.

2. Static vs Dynamic Efficiency

There is a fundamental short-run/long-run distinction when assessing the efficiency (i.e., the cost effectiveness) of policies for climate change mitigation. In the short-run, cost minimisation depends on agents' operational decisions, which are conditional on existing capital and technology. In the long-run, cost minimisation also depends on investment decisions, which determine capital and technology through time. Accordingly, the EU ETS can be assessed both with respect to its static (short-run) efficiency and with respect to its dynamic (long-run) efficiency.

In principle, cap-and-trade systems such as the EU ETS are static-efficient by nature: emissions are cut at the least total cost, as the market mechanism equalises marginal abatement costs across regulated

1. The cap declines each year by 1.74% compared to 2010, the mid-point of Phase II (2008-2012).
2. The MSR (Decision (EU) 2015/1814) is a rule-based mechanism that limits the excess supply of emission allowances. The MSR will start operating in January 2019.
3. The workshop's programme and contents are available on the project's website.



entities.⁴ By contrast, establishing whether the EU ETS is dynamic-efficient, that is, whether it induces investments that allow minimising abatement costs over the long term, is more complicated. Operators' expectations on investment returns, and thus their investment decisions, are affected by uncertainties intrinsic to the EU ETS concerning future carbon prices and possible regulatory changes, as well as by a multitude of other market and policy factors. Moreover, while in principle the EU ETS is static-efficient, independent of the way the allowances are distributed,⁵ the same is not true for its dynamic efficiency. This is because whether allowances are received for free or not may change – *ex-ante* – the relative convenience of alternative investments and, therefore, determine different investment decisions. As pointed out by one of the participants in the workshop (Section 5), and as confirmed by some empirical findings (Section 3), free allocation is one element of the EU ETS that can affect its dynamic efficiency.

3. The Empirical Evidence

There are a significant, though not a huge number of empirical studies on the impact of the EU ETS on low-carbon innovation and investment. Taken together, they hardly offer an exhaustive supply of evidence and, in relative terms, are fewer than those looking at other aspects of the EU ETS, such as competitiveness effects. Moreover, the empirical evidence is, as yet, limited to Phases I (2005-2007) and II (2008-2012). This means, crucially, that any potentially relevant effects of regulatory changes introduced with Phase III, notably the replacement of grandfathering with auctioning as the default

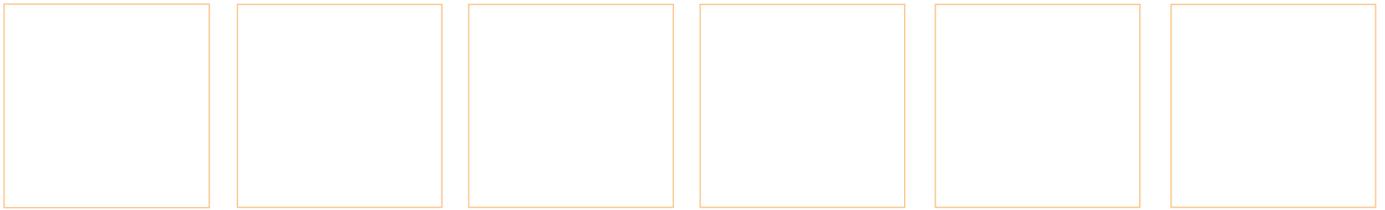
allocation method (for the power sector) and the use of efficiency benchmarks for the remaining free allocation, are not yet quantified.

Our review identified 22 articles, here divided into two categories: those using econometric techniques (seven) and the others (fifteen), which are largely qualitative and descriptive analyses.⁶ Econometric analyses in this domain are limited by the paucity of suitable databases. Non-econometric studies draw on more limited information, often derived by the authors through *ad-hoc* interviews. There follows a summary of the main evidence emerging from the two literature subsets.

3.1 Econometric Literature

Calel and Dechezleprêtre (2016) estimate the impact of the EU ETS on low-carbon patenting. It is a study that stands out in this literature for four reasons. First, patent counts are an objective measure of innovation; albeit only a proxy for the number of innovations translating into new production processes or products. Second, the firms in the sample operate over 80% of all EU ETS installations. Third, the approach used (difference-in-differences) offers a clear-cut causal interpretation of the estimated effect. Fourth, the main result for the magnitude of low-carbon innovation brought about by the EU ETS is significantly more positive than most other studies would suggest. The authors find that the EU ETS caused a 36% increase, over 2005-2009, in the number of low-carbon patents granted to regulated firms. Other relevant results from the study are that: *a*) no evidence of an indirect innovation effect on non-regulated entities is found; and *b*) that the surge in the total number of low-carbon patents observed

4. According to the independence property, the market equilibrium in a cap-and-trade system is cost-effective and independent of the initial allowance allocation. A number of factors, however, can lead to the independence property being violated, including transaction costs, market power and price uncertainty (Hahn and Stavins, 2011).
5. Operational decisions are independent of the way allowances are acquired. In either case, using allowances for compliance entails a cost: a real cost, with auctioning; an opportunity cost, with free allocation.
6. The full list of studies will be available in the assessment report produced by the LIFE SIDE project.



over the period in question was primarily driven by rising energy prices.

Martin *et al.* (2013) is a second important econometric study investigating the determinants of low-carbon innovation, here measured by any R&D activity aimed at curbing emissions or energy consumption or at developing products that can help customers to reduce their emissions. It uses primary data from interviews conducted in 2009 with the managers of 770 manufacturing firms in six European countries. The study finds several interesting results. First, the responses indicate that most firms are engaged in climate-related innovation (and that this effort was focused on process rather than product innovation). But they also show that no statistically significant difference was found between firms regulated by the EU ETS and non-regulated ones. Second, significant differences in the propensity to innovate were found across sectors and countries. Third, low-carbon innovation is positively associated with firms' expectations on the stringency of their future allocation. Fourth, firms positioned just below the established thresholds for receiving free allowances in (subsequent) Phase III⁷ engaged more strongly in low-carbon innovation. This last result is presented as evidence of a causal negative effect of free allocation on low-carbon innovation.

Schmidt *et al.* (2012) analyse the effects of the EU ETS and long-term emission reduction targets, as they are perceived (as opposed to what they are by some objective metrics), on investments in technology adoption and on R&D. The study is based on interviews with the managers of 65 firms producing electricity and 136 firms providing technology for electricity generation, in seven European countries. The effects are measured by the respondents' answers to the questions about the change and direction of innovation investments between the periods

2005-2009 and 2000-2004. Among other results, the authors find evidence that not only did the grandfathering of emission allowances in Phases I and II hamper low-carbon technology adoption. It also effectively incentivised the adoption of emitting technologies. Long-term emission reduction targets, nonetheless, are an important R&D trigger.

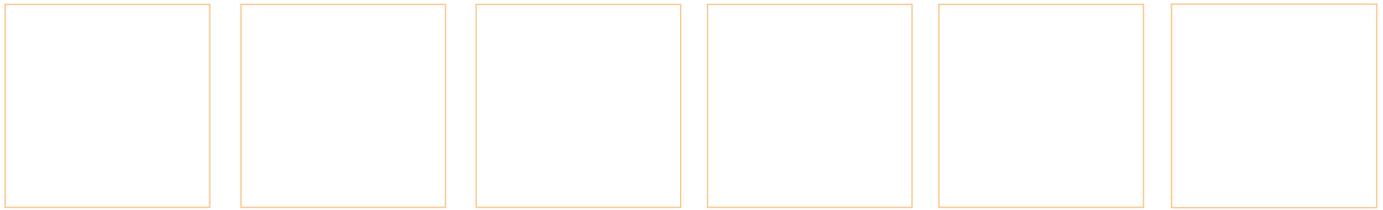
While, to some extent, results vary across sectors and countries, some robust evidence emerges from the econometric literature, which includes the three studies outlined above and only a few more (namely, Lofgren *et al.*, 2014; Bel and Joseph, 2015; Borghesi *et al.* 2015; and Lundgren *et al.*, 2015). Most often, the role of the EU ETS in driving low-carbon innovation is judged to have been limited, especially when compared to that of energy prices. In Phases I and II, the EU ETS appears to have fostered incremental emission reductions, above all, through fuel switching and small-scale investments of regulated firms in energy efficiency. Seemingly discordant are the findings of Calel and Dechezleprêtre (2016), which show the innovation effect as measured by patenting to have been substantial.⁸ In general, there is a consensus that the surplus of allowances in the carbon market and the corresponding impact on the carbon price negatively affected low-carbon innovation and investment. Grandfathering – a feature of the EU ETS in Phases I and II – is also identified as having been a major factor limiting the ability of the EU ETS to incentivise low-carbon innovation and its uptake.

3.2 Non-econometric Literature

Most of the studies on the impact of the EU ETS on low-carbon innovation and investment offer qualitative or descriptive analyses. We found fifteen such studies, most of which (twelve) are based on primary information collected through *ad-hoc* interviews, typically with managers of regulated firms. These

7. Such thresholds are based on sectoral trade and carbon intensities.

8. A legitimate hypothesis for this discrepancy is that a significant share of patented innovations had not (perhaps, not yet) translated into new operating production processes or commercialised products.



studies tend to be country and sector specific, with five focused on the electricity sector and five on the paper sector (one on chemicals and four covering multiple sectors). Some are sufficiently narrow in scope to qualify as case studies.

Among the insights offered by these studies, those concerning the incentives for low-carbon innovation and investment are most relevant. The electricity sector is of special interest here. First, the electricity sector is expected to be fully decarbonised before the others. Second, the electricity sector underwent a fundamental change in regulatory regime in passing, with Phase III, from grandfathering to full auctioning. In the first two trading phases, perverse incentives created by the new-entrant and closure provisions on the allocation and withdrawal of allowances, respectively for new and closing installations, are frequently stressed. Allowances granted to new installations effectively improved the economic attractiveness of investments in CO₂-intensive generation. Closure provisions, whereby operators forfeit the allowances allocated to the installations they close, effectively incentivised the protracted operation of high emitting installations. These unintended incentives vanished with Phase III, as electricity producers ceased to receive free allowances. In fact, even before the start of Phase III, there is evidence (based on interviews with stakeholders) that the expectation of auctioning caused the cancellation of planned investments in coal power plants. The same literature documents the increased interest in R&D activities related to Carbon Capture and Storage (CCS), which did not, however, last long due to high costs when compared to the level of carbon prices

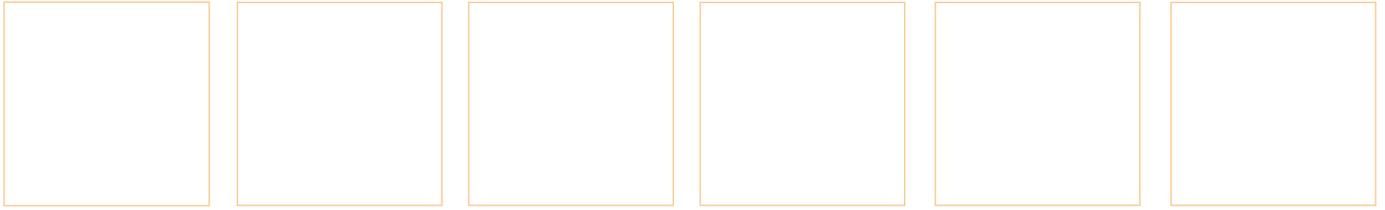
(limiting the economic viability of such investments) and issues of local social acceptance.

Further insights specifically offered by the non-econometric literature concern organisational innovation. Following Rogge (2016), organisational innovations can be classified by whether they relate to: firms' business practices (e.g., implementing monitoring, verification and reporting of emissions, or participating in carbon trading); workplace organisation (e.g., making the EU ETS a top management issue); or external relations (e.g., collaboration with other firms or public institutions). The EU ETS has been generally successful in these respects.

4. The EU ETS Funding Programmes for Low-Carbon Innovation

Irrespective of its level, the role of carbon pricing in spurring low-carbon innovation is not exhaustive. Above all, since innovative projects are risky by nature, they require specific forms of financing.⁹ NER 300 is the EU ETS funding programme for highly innovative low-carbon projects in the pre-commercial demonstration phase.¹⁰ The sale of 300 million emission allowances in the New Entrants Reserve of the EU ETS¹¹ generated €2.1 billion, which were awarded in two rounds (in December 2012 and July 2014) to one CCS project and to 38 renewable energy projects. As only three of the 39 projects have so far entered into operation, it is too early to draw definitive conclusions on the programme's performance. Nevertheless, some lessons have already been learnt¹². There are three critical points in NER 300 limiting its effectiveness. First, as a rule, funds

9. For a discussion of the rationale for and recommendable features of public support for low-carbon innovation, see Mazzucato and Semieniuk (2017) and Nemet *et al.* (2016).
10. NER300 is established by Art.10a(8) of the EU ETS Directive. The rules of the funding scheme are specified in Commission Decision 2010/670/EU.
11. The New Entrants Reserve is an EU-wide pool of emission allowances set aside for new and expanding installations eligible for free allocation.
12. The impact assessment accompanying the proposed revision for Phase IV (SWD (2015) 136) provides a detailed account of NER 300 and useful information on the future Innovation Fund.



are given out upon a project's success.¹³ While this responds to the intent of guaranteeing good use of public money, risk-free innovation funding clashes with the nature of innovative projects, which are risky at least to some degree. Second, funds can only cover up to 50% of the project's additional cost of innovation. This condition is to make firms leverage additional funding from other sources. But the project promoter may struggle to secure the extra financing. Third, available funding may be insufficient for the more expensive projects involving breakthrough technologies such as CCS.¹⁴

The proposed revision for Phase IV introduces the Innovation Fund (IF), which will be an enhanced version of NER 300. At present, only a few basic features of IF are defined. The scope of the programme will be wider compared to that of NER 300, both in terms of the resources made available and in terms of the range of eligible beneficiaries. The financial resources will be generated by the sale of up to 450 million allowances and projects specific to industrial sectors will be funded, too. The maximum funding rate will be raised to at least 60% and fund disbursement is to be partially based on the achievement of milestones in the project's development. Based on recent consultations that the EC has conducted with the stakeholders¹⁵, it seems likely that further changes will be adopted. While the IF will still use grants, these may be accompanied by other ways of financing eligible projects. Some diversification in financial instruments, including loans, guarantees or equity, may be tailored to projects with different risk profiles. This would result in more financial resources being leveraged. Furthermore, concerning the selection of the projects, their ranking may not

be exclusively based on individual 'value for money' in terms of emissions abatement.¹⁶ They may also consider the potential for wider benefits emerging from cross-sector cooperation.

5. Insights from the Workshop

The LIFE SIDE workshop on low-carbon innovation and investment in the EU ETS brought together about 25 experts. These included analysts from universities and other research institutions, policy-makers and representatives of regulated industries and of NGOs. A selection of the relevant points that were made on that occasion is reported below.¹⁷

- There is a compelling economic case, related to innovation spillovers, scale and network economies, competitiveness preservation and energy security, for complementing the EU ETS with stronger R&D policies.
- In the EU, spending on direct support for renewable energy sources at the deployment level has so far dwarfed R&D support.
- Contrary to previous years, figures on European patents for 2014 and 2015 show a reduction in the share of new low-carbon patents as part of total new patents awarded. This is a reason for concern. A period of lower fossil fuel prices as well as the surplus of allowances and the corresponding impact on carbon prices in the EU ETS appear to be contributing to reduced incentives for clean innovation in Europe.
- Free allocation that is not technology neutral, as with grandfathering (but, in theory, with the

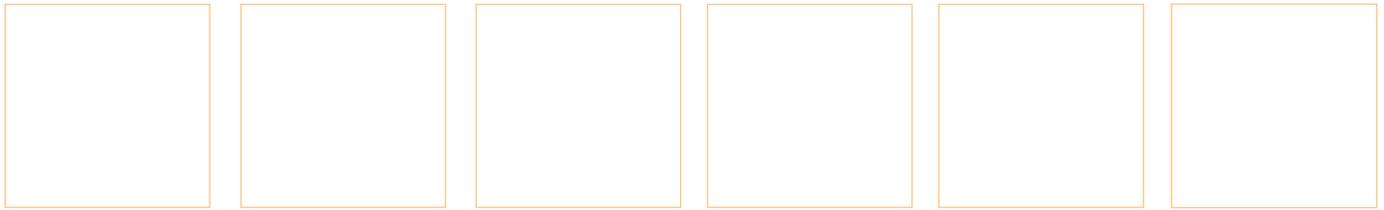
13. Up to 60% of the funding awarded can be provided upfront, but conditionally on a MS providing an appropriate guarantee.

14. The funding awarded to the one CCS project (€300 million) only covers 34% of its additional costs.

15. The results of a series of workshops instrumental in the design of the IF are summarised in Climate Strategy (2017).

16. Under NER 300, projects were ranked by their cost-per-unit performance, the performance being the amount of renewable energy produced or the amount of CO₂ stored in the case of CCS projects.

17. The workshop was held under Chatham House rules and, therefore, no names can be revealed in this section.



current benchmarking system too¹⁸) may affect investment decisions. This is because it may alter the economic ranking of possible alternative investments.¹⁹

- EU ETS auction revenues collected by MS can be used for supporting low-carbon innovation (or for other climate-related purposes). Their formal earmarking, however, is not straightforward. Even among economists, the earmarking of fiscal revenues is a disputed issue, given the potential opportunity cost for the government in committing money to a certain use. According to a survey-based study carried out under the LIFE Maximiser project (www.maximiser.eu), in 2015 MS used on average 85% of their EU ETS auction revenues (slightly smaller shares in 2014 and 2013) to tackle climate change. However, the responses provided by MS did not specify whether these resources were used to finance climate-related programmes beyond those already in place.
- Decarbonisation will require new collaboration models between industrial sectors. In some cases, the cost of decarbonisation through enhanced ‘industrial symbiosis’ may be relatively small. For example, convenient opportunities for the decarbonisation of the iron and steel sector could arise from the better alignment of incentives with the construction sector, as happened with the automobile industry following the imposition of fuel efficiency standards. In general, however, deep decarbonisation through industrial symbiosis, including progress towards a circular economy, requires massive levels of investment.

- As the carbon price signal is, to varying degrees, muted along the value chains, introducing a consumption charge (of a special kind) on carbon-intensive materials was proposed as a way to reinstate the signal and, thus, the incentives for abatement.²⁰

6. Conclusions

The success of the EU ETS is vital for the full decarbonisation of the European economy. Continued progress in low-carbon innovation and investment on the part of firms regulated by the EU ETS is necessary both for meeting the EU’s long-term mitigation targets and for minimising related costs.

The existing empirical literature on the effects of the EU ETS on low-carbon innovation and investment only concerns Phases I and II. Thus, potentially relevant effects of regulatory changes introduced with Phase III are not yet appreciated. A recurring indication is that, in the first two trading phases, the impact of the EU ETS on low-carbon innovation has been moderate. However, the findings of one prominent econometric study (Calel and Dechezleprêtre, 2016), which measures innovation output by patent counts, present a more positive picture here. The literature also indicates that low-carbon innovation efforts have focused on production processes more than on products, and that heterogeneity in the propensity to innovate is significant across sectors and countries. As regards the diffusion of low-carbon technologies, investments induced by the EU ETS are typically described as small-scale with short amortization times (e.g., three to five years), resulting in incremental emission reductions.

18. For example, the benchmark values for ‘Bottles and jars of colourless glass’ and for ‘Bottles and jars of coloured glass’ are 0.382 and 0.306 (allowances/tonne of output), respectively.

19. Retrospectively, the switch from grandfathering to auctioning for the electricity sector seems to provide an example in point: a few studies (e.g., Rogge and Hoffmann, 2010; Pahle, 2010) document that investment plans in new coal power plants were cancelled when it became clear that grandfathering (more favourable to CO₂-intensive plants in terms of allowances per KWh generated) would cease as of Phase III.

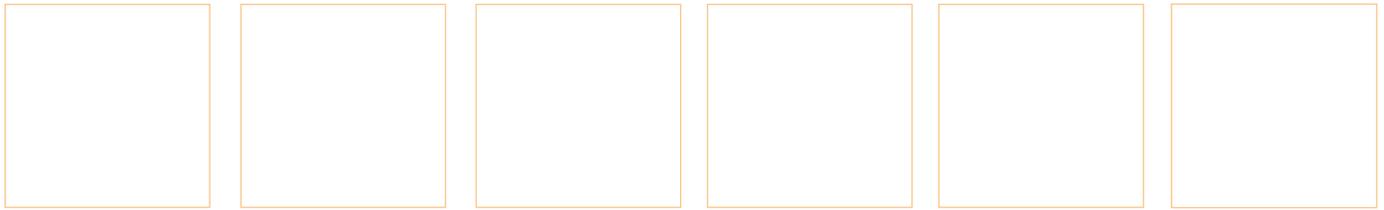
20. The details of this proposal are in Neuhoff *et al.* (2016).



The level of ambition of the EU ETS as reflected in the level of carbon prices (both present and future) is the main parameter determining the strength of the incentives for low-carbon innovation and investment. Regulatory uncertainty is a variable of primary importance affecting firms' investment decisions and free allocation plays a role too. Accordingly, tightening the cap and extending allowance auctioning in a predictable normative context are the most frequent recommendations for strengthening incentives. It is equally clear, however, that the effectiveness of such measures depends on multiple exogenous factors (Elkerbout and Egenhofer, 2017) and that additional complementary policies are necessary. In the first place, greater financial support is needed both for R&D activities and highly innovative projects that have not yet reached commercialization. The establishment of the MSR and the proposed revision for Phase IV demonstrate that the policymaker, while subject to multiple constraints (not least that of preserving the competitiveness of European industry), recognised these points.

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- *Free allowance allocation in the EU ETS;*
- *The EU ETS and its interaction with other climate and energy policies;*
- *Low carbon investment and innovation in the EU ETS;*
- *The International dimension.*

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