

# Decarbonizing the Industrial Sector: The potential for ambitious EU member states to use flexible performance standards to strengthen carbon price signals

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## Summary

In this policy brief, we offer an introduction to the family of policy instruments known as “flexible performance standards.” We describe and examine the attributes of performance standards that elevate them to be chosen in many jurisdictions, often as a precursor to carbon pricing, and we explain why flexibility improves their cost-effectiveness and the potential they may have as complementary policies to strengthen carbon pricing to drive innovation, with a specific focus on the industrial sector. The brief ends with a discussion of the potential to apply flexible performance standards to the Swedish industrial sector to achieve emissions reductions in line with the national climate target.

## Introduction

Even as carbon pricing to combat climate change is increasingly implemented in many countries,<sup>1</sup> the scope of such policies is often too narrow, and prices remain too low to deliver on the objectives of the Paris Agreement (World Bank 2019). The incomplete coverage of carbon pricing across sectors and jurisdictions undermines the ability of any individual nation or group of nations to adopt rigorous carbon pricing sufficient to reach the agreed-upon climate targets (2 or 1.5 degrees above preindustrial limits).

Nonetheless, economic evidence from theory and experience in practice indicates that carbon pricing is the most cost-effective way to accomplish emissions reductions. Cost-effectiveness is crucial for achieving such goals because the total cost may be high. With incomplete coverage, the cost of introducing a high carbon price for any individual nation is magnified by the prospect of losing economic activity to nations that do not regulate carbon aggressively. This is especially relevant for Sweden, which, as a leadership nation, has adopted a net-zero climate stance for 2045.

The EU's Emissions Trading System (ETS), in which Sweden participates, was implemented to deliver a price on carbon emission in the electricity and industrial sectors.<sup>2</sup> The ETS was envisioned to become the cornerstone of the EU's climate policy and to coordinate a role for carbon pricing across the EU to mitigate the economic cost of member states acting alone. The ETS has not heretofore achieved a carbon price consistent with achieving Sweden's national goal. Since the beginning of the ETS in 2005, the price of allowances has oscillated at levels insufficient to drive investments that would achieve the desired energy transformation. In 2018, with the implementation of various reforms, the market witnessed a sharp increase in prices that appears to have affected emissions outcomes in the electricity sector (Agora Energiewende and Sandbag 2020). However, prices remain too low to drive investments in the industrial sector, and measures to protect against international competition have suppressed the pass-through of allowance prices to product prices in industry, leaving largely unrealized any influence of an embedded carbon price in the consumption of industrial goods. Recently, in the shadow of the COVID-19 crisis, prices have fallen again.

The new president of the European Commission, Ursula van der Leyen, has expressed a strong ambition for the European Green Deal, including broadening the scope of carbon pricing within the EU and implementing more ambitious climate targets. Nonetheless, carbon pricing continues to face obstacles. Individual ambitious member states need to understand effective and viable policy options that can supplement an ETS carbon price to accelerate innovation and investment if the price remains modest. We suggest that flexible performance standards could be implemented by an individual member state, such as Sweden, or a group of member states, and may be a valuable companion instrument to carbon pricing.

### The Dilemma of Low Carbon Prices

The most prominent problem with a weak carbon price is that it does not provide enough incentive to invest in new technology and innovation activities to reach long-term climate targets. It also undermines public confidence in emissions trading as an effective climate policy and encourages the development of other policies and regulations. Implemented in an uncoordinated way, a portfolio of overlapping policies risks transmitting a disparate array of implicit carbon prices that reflect a wide range of resource costs to reduce carbon emissions, imparting inefficiency and raising the cost of

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<sup>1</sup> <https://icapcarbonaction.com/en/icap-status-report-2020>

<sup>2</sup> At the EU level, carbon pricing does not affect the building and transportation sectors.

climate policy. The low allowance prices in the carbon market inaccurately signal to policymakers that costs are quite low, because the costs of overlapping policies are usually hidden; the regulator is also likely to miss many cost-effective opportunities for reducing emissions in the short term, which carbon pricing would be expected to identify.

Regulatory policies at the national and subnational levels achieve many emissions reductions from the sources they regulate; however, where these sources are also regulated under the EU ETS, the overlap of policies has given rise to a form of carbon leakage *within the ETS* commonly referred to as the “waterbed effect.” A waterbed is analogous to an emissions cap because it contains a specific volume; pushing down in one place causes the water to push up somewhere else. In the EU ETS, the waterbed effect is the phenomenon whereby, if any EU member state implements measures to reduce emissions at emitting facilities covered by the emissions cap, those reductions make allowances available and so emissions increase in another member state.

In the EU and elsewhere, regulatory policies have always preceded carbon pricing. These policies, aimed for example at improving energy efficiency in appliances, cars, industry, and buildings, appear valuable in assembling constituencies over time that support ever more stringent energy and climate policy (Meckling et al. 2017; Pahle et al. 2018). A practical challenge to current carbon pricing is that low carbon prices have motivated many jurisdictions to strengthen existing regulations and implement additional policies that overlap with carbon pricing, sometimes to the exclusion of carbon pricing. Examples in the EU and North America include increasingly stringent renewable energy technology goals, investment and production tax incentives, standards that regulate emissions of fugitive methane, and emissions intensity standards in transportation fuels. In addition, jurisdictions have amplified consideration of climate outcomes in regulating industrial permitting, land use, and other administrative functions.

The paradox for a nation such as Sweden is that its leadership efforts to reduce emissions through regulations might leave the total quantity of emissions unaffected. If such efforts trigger the waterbed effect, overlapping policies will be almost futile in reducing carbon dioxide emissions and ultimately drive down the carbon price even further. The Market Stability Reserve in the ETS may help arrest this feedback by withholding allowances from the market when allowances are plentiful and allowance prices are low (Burtraw et al. 2018; Perino and Willner 2016 and 2017). A price floor in the ETS would support prices even more directly (Fischer et al. 2020). Nonetheless, to the degree that prices continue to fall, they might unleash a vicious cycle, where low prices motivate even more stringent local regulations. Taken to the extreme, collective unilateral actions could render the EU ETS irrelevant, replacing it with a patchwork of national policies (Flachsland et al. 2020).

## **The Challenge of the Industrial Sector**

If the EU seeks to achieve the greatest emissions reductions possible in the industrial sector using carbon pricing, it may trigger a second form of carbon leakage by promoting the migration of economic activity and emissions to unregulated jurisdictions *outside the ETS*. Given this concern, EU policymakers have not necessarily lacked ambition; they may need additional tools to address the challenges from international competition facing the industrial sector.

In this context, we examine flexible performance standards as a policy instrument that preserves or amplifies many elements of carbon pricing and avoids some of the challenges of more ambitious pricing by mitigating the threat to competition from unregulated jurisdictions. We are especially interested in the application of performance standards at the level of one or a group of member states, their interaction with the EU ETS, and the possibility that they could provide an on-ramp to potential expansion of carbon pricing over time.

The potential contributions and limitations of flexible performance standards can be described in the context of a general equilibrium reasoning that identifies opportunities for emissions reductions via three economic channels: *input substitution* addresses opportunities such as fuel switching, *change in production* transforms processes or adds pollution controls, and *output substitution* addresses opportunities for consumers to substitute away from products with high levels of embodied emissions (Goulder 1999). Economic efficiency requires that all three avenues be operational. Economy-wide emissions pricing can invoke responses in all three channels and improve efficiency by transmitting an incentive to reduce the residual emissions that occur even with modern pollution controls in place (Spulber 1985). This third channel for output substitution in this paradigm poses especially difficult challenges for the industrial sector because it embodies the carbon price in final product prices, which may stimulate consumers to substitute away from domestically produced emission-intensive products to products from unregulated jurisdictions.

Although modest emissions reductions in the industrial sector are often available in the short run, substantial reductions require substantial innovation, which has even greater relevance if one considers the tremendous investment and growth in greenhouse gas emissions expected in the industrial sector in developing countries.<sup>3</sup> A fundamental characteristic of the industrial sector is long-lived capital: investments made in this decade using conventional technology will lock in infrastructure for the rest of the century. A modest carbon price today is insufficient to alter the technological structure of the industrial sector even in anticipation of a higher carbon price in the future, because uncertainties such as the possibility of policy reversal, especially in emissions pricing, raise the hurdle rate for new investments (Löfgren et al. 2008). In addition, industrial firms need assurance that they will enjoy sustained demand for their product and will not be undermined by output from firms in other jurisdictions that do not make efforts to reduce emissions.

One way to navigate this conundrum may be to relax the comprehensive economic model by weakening the incentive for output substitution—the third channel for emissions reductions that is triggered by changes in product prices—and amplify incentives for input substitution and changes in production. This approach is embodied in flexible performance standards.

## Introduction to Flexible Performance Standards

Flexible performance standards are analogous to performance *benchmarks* that already exist in the EU ETS.<sup>4</sup> Technology-neutral emissions rate benchmarks describe the best-performing ten percent of manufacturing installations for 54 product categories in the ETS. These benchmarks serve as the basis for the free allocation of emissions allowances to industry.<sup>5</sup> The benchmarks cover all production-related direct emissions, including emissions related to the generation of measurable heat used for production, and decline linearly over time. Firms with a greater emissions rate than the best-performing ten percent of the sector can purchase emissions allowances from other firms or sectors covered by the trading program; firms with a lower emissions rate can sell allowances into the market. Crucially, the allocation provides an incentive to maintain production at regulated facilities because the allocation will adjust if production levels change.

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<sup>3</sup> Gonzales et al. (2020) identify opportunities for substantial emissions reductions in US industry by imposing standards to bring the population of emitting facilities up to best practice.

<sup>4</sup> Note that the word “flexible” indicates that a performance standard is not binding, because a firm can have an emissions rate above the standard if it pays for credits for the emissions above the standard. Under a nonflexible performance standard, if a firm violates the standard, it can be subject to large fines.

<sup>5</sup> [https://ec.europa.eu/clima/sites/clima/files/docs/ets\\_handbook\\_en.pdf](https://ec.europa.eu/clima/sites/clima/files/docs/ets_handbook_en.pdf)

An example of a performance benchmark that is independent of a carbon pricing policy but overlaps carbon pricing is the California Low Carbon Fuel Standard (LCFS). The LCFS requires the life-cycle carbon intensity of transportation fuel (tons/joule) to be reduced by 10 percent by 2020 and 20 percent by 2030. Refineries can comply through a variety of methods, including improvements in refinery operations, better feedstock, introducing corn or cellulosic ethanol and biodiesel to refinery products, natural gas or hydrogen, or credits created by using electric vehicles. This program differs from the EU ETS because the intensity standard is used to measure the compliance obligation rather than eligibility for free allowances. No emissions cap exists, so emissions could vary under the LCFS as overall economic activity varies. The LCFS overlaps with the California economy-wide cap-and-trade program, so any changes in emissions associated with transportation fuel must be offset by emissions changes in other covered sectors. This is analogous to the EU ETS, where emissions from the industrial sector in total can change if allowances are exchanged with the power sector.

Other examples of flexible performance standards that allow trading include vehicle fleet efficiency standards and electricity sector renewable portfolio standards. Together, these policies in Europe and their parallels in the US have contributed the major portion of reductions in greenhouse emissions to date. Importantly, both types of standards have evolved over time to introduce greater flexibility and technological neutrality. For example, the California renewable portfolio standards require renewable energy resources to constitute 60 percent of electricity consumption by 2030; it evolves into a 100 percent nonemitting standard by 2045 that offers greater technology neutrality.

Flexible performance standards and benchmarked allocation of emissions allowances in the EU ETS have a common feature—they reduce the change in product prices that take place in conventional emissions pricing. This outcome occurs because these instruments are two policies in one. First, like ordinary cap and trade, they introduce a cost (shadow price) on emissions. If a firm can reduce its emissions, it can trade the emissions allowances or credits that it does not need, and if it increases emissions, it must obtain additional allowances or credits. Second, they provide a quantity of allowances or credits (denominated in tons) to the firm that is calibrated to the standard of performance (tons/output) and tethered to the firm's level of production (output). Algebraically, the performance standard allocates credits the same way that benchmarks do in the EU ETS, as a product of the emissions rate and output:  $(\text{tons} / \text{output}) \bullet (\text{output}) = (\text{tons})$ . If a firm expands its production, it earns additional credits that reduce its marginal production costs compared to having to purchase emissions allowances in an auction, and if its emissions rate is below the standard, it profits on every unit of production by selling unneeded credits that it has earned. The flexible performance standard thus combines a carbon price with a production incentive, and by reducing marginal production costs compared to carbon pricing, it leads to reduced prices for the final product, a key concern of industry. Put simply, the performance standard introduces a price on the externality that is like a carbon price, but it keeps the revenue (externality value) within the sector, providing capital for investment.

## The Swedish Context

Carbon pricing is the central pillar of Swedish climate policy. A national carbon tax that covers the transport sector is by far the highest in the world (around 100 euro/ton CO<sub>2</sub>e) (World Bank 2019). The Swedish energy sector is covered by the EU ETS; however, distinct from most EU member states, it is basically carbon neutral. A portion of the industry sector's emissions is subject to the carbon tax, primarily covering the manufacturing and food industries and corresponding to less than 10 percent of total industrial emissions.<sup>6</sup> However, most of the industry sector, including iron and steel

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<sup>6</sup> <http://www.enveco.se/wp-content/uploads/2018/12/Styrmedelsverkan-inom-icke-handande-sektorns-industri.pdf>

production, minerals (cement), oil refineries, and chemical industries, is covered by the EU ETS. These sources account for approximately 80 percent of total Swedish greenhouse gas emissions covered by the EU ETS and approximately one-third of total Swedish emissions. Five large companies or facilities are responsible for almost 50 percent of the emissions from the industrial sector.<sup>7</sup>

The persistently low carbon price in the EU ETS since its introduction in 2005 has, as discussed, created a basis for complementary policies in EU member states, including Sweden, such as targets for renewable energy and green electricity certificates. In turn, these policies have exerted a downward pressure on the EU ETS price. Consequently, the EU ETS market has provided little (or no) incentive for innovation or investments in more costly (and risky) technologies, such as carbon capture and sequestration.

In line with the research literature showing that carbon pricing should in many cases be complemented with support for research and development (see, e.g., Popp 2019; Jaffe et al. 2005) the Swedish government also supports clean innovation. The *Industriklivet* (“Industry Step”) offers investment support to industry (approximately 60 million euros/year), but more targeted support programs also exist, such as *Hybrit*, a partnership between steel and energy actors with support from the Swedish Energy Agency (50 million euros in total), which aims to develop fossil-free steel production. While this project is quite high risk, if successful, it could reduce Sweden's total greenhouse gas emissions by about 10 percent.

Sweden also has a long tradition of joint efforts and dialogue between industry and the government. Before the COP15 meeting in Paris in 2015, the Swedish government appointed a coordinator for such a collaborative initiative: Fossil Free Sweden<sup>8</sup>. Sectors and industries have since then developed several “roadmaps” identifying barriers and challenges to reach the 2045 net-zero target (19 reports have been published by different sectors and industries, and two more are under way). Several of those roadmaps identify policies, particularly the EU ETS, as crucial for reaching the climate target, but strategies to overcome other types of challenges and barriers are also highlighted, such as improvements to inefficient license processes, better use of procurement rules, and mitigating the risks of transformative investments.

## Implementing Flexible Performance Standards within Sweden

The Swedish Climate Policy Council identifies industry as a key sector for Sweden to reach the 2045 climate goal of net zero emissions but concludes that even with the current policies, the necessary incentives to drive industrial decarbonization do not exist (Swedish Climate Policy Council 2020). Given the importance of the industrial sector and the benefits of the aforementioned flexible performance standards, we examine how such a policy might complement carbon pricing to promote innovation in the industrial sector in Sweden.

Fischer (2019) explains that driving innovation without harming industry competitiveness might be achieved in three ways. The first is a tax that rebates revenues based on output shares within the regulated industry; the second is an emissions cap that distributes allowances for free based on output shares. Both methods, which occur under the EU ETS product benchmarks, address the concerns of industries that are trade exposed and energy intensive. Firms in these industries will necessarily incur production and abatement costs if they try to achieve emissions improvements; this is illustrated by the triangles in Figure 1. Even after taking steps to reduce emissions, under a conventional emissions

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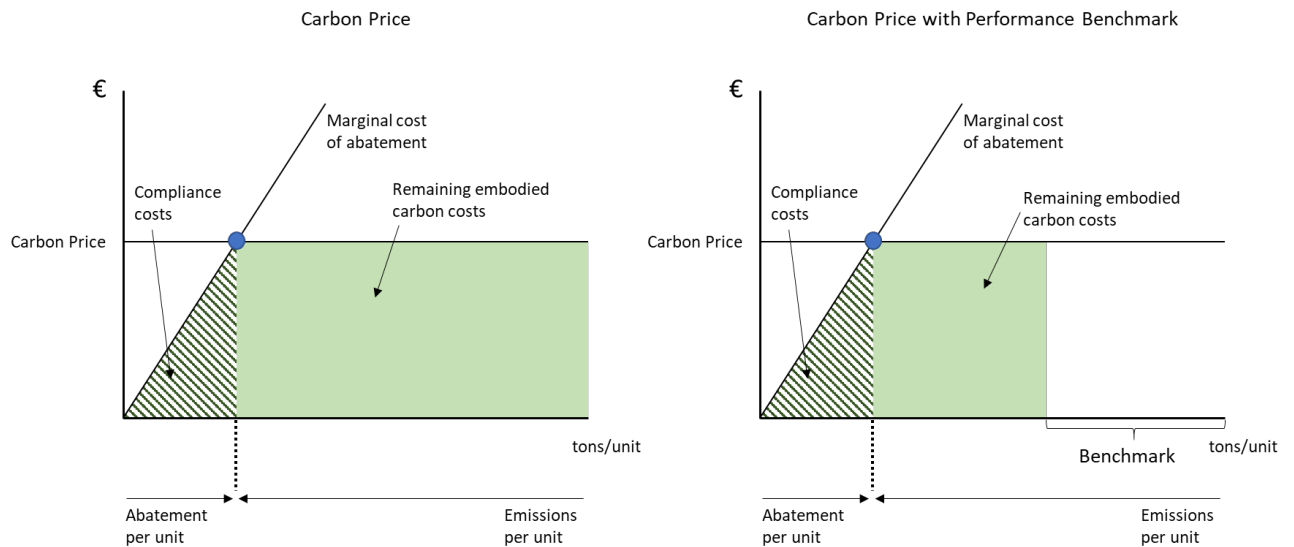
<sup>7</sup> SSAB EMEA Oxelösund, SSAB EMEA Luleå, Cementa in Slite, Lulekraft in Luleå, and the Preem refinery in Lyseki.l

<sup>8</sup> <http://fossilfritt-sverige.se/in-english/>



tax or cap-and-trade program, they would face a cost for the remainder, illustrated by the rectangle. However, tax rebates or free allocation of emissions allowances reduce the total cost to the firms. For example, under emissions trading, the *total allowance cost* of each entity will depend only on the cost of buying potentially necessary *additional allowances* beyond what is received for free; in fact, the total allowance cost could be negative if the firm has allowances to sell. On the other hand, the *marginal carbon cost*, which provides the incentive for firms to mitigate carbon emissions, will be (approximately) the same allowance price as under conventional cap and trade because that is the cost per ton avoided by reducing emissions.<sup>9</sup>

**Figure 1.** Total and marginal costs of emissions pricing per unit produced



Source: Adapted from Fischer (2019).

However, such tax or trading proposals may not fit well in Sweden currently. With the existing policies, an additional carbon tax with a fixed price would not be tethered to a tangible innovation goal, and introducing a sector-specific emissions cap may be difficult to justify because it may appear to be too narrow and to limit economic growth.

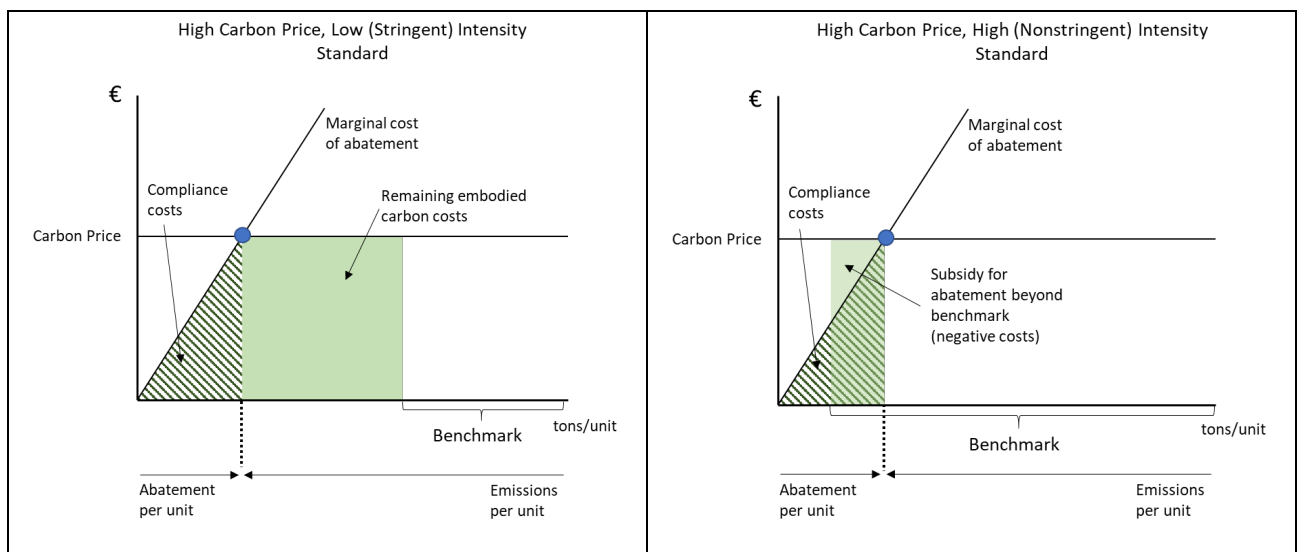
The third option to drive innovation without harming industry competitiveness is a flexible (emissions intensity) performance standard. This instrument is like the other two approaches (tax or trading proposal), but it can be tied to achieving a rate of technical progress and would also reveal a price that would adjust to achieve that outcome. Unlike a sector-specific emissions cap, it would not appear to constrain overall activity in the regulated sector(s).

So how would a flexible performance standard work? One way to harvest efficiency lies in the possibility of trading credits between entities with different costs, but this is especially challenging for a country such as Sweden that has only a limited number of national industrial actors, which means that the efficiency gains of trade are limited. In fact, this points to an important design issue: the flexible performance standard policy can be implemented without trade and possibly evolve to a tradable performance standard scheme over time.

<sup>9</sup> The allowance price under this policy will differ from conventional cap and trade because the output level will differ.

Figure 2 shows that the innovation margin hinges on the marginal carbon price. Depending on the stringency of the intensity standard and the level of emissions abatement, without trading, the government is effectively either taxing or subsidizing producers for the difference between their emissions (per unit) and the standard. Two components affect the producer costs in this case: the price of the credit and the stringency of the intensity standard. If a low (stringent) standard is set and the credit price is high, then the marginal and total costs to producers would be high (Figure 2, left panel). If a high (nonstringent) standard is set while the credit price is still high, the marginal cost would be equally high (meaning it would have the same marginal effect on the innovation margin), but the total cost to producers would be reduced (Figure 2, right panel). In the latter case, producers may reduce emissions more than required by the high standard, and to preserve the innovation margin, the government would be required to pay producers for emissions abated below the standard. Government revenue would be less and potentially negative in that case.

**Figure 2.** Firms may face negative or positive rewards under a performance standard.



Hence, government may create a strong innovation incentive using a high carbon price and still protect producers' competitiveness through subsidies. If the policymaker is planning to use large public funds to support clean innovation, then devoting part of that to subsidies within a performance standard scheme could be a wise way to provide incentives for industry to accelerate innovation and investment. In this way, the policymaker will not only support the industry but do so using a higher marginal carbon price; if multiple producers are involved, those producers that perform best in relation to the standard will gain the most. This approach also has the advantage of being able to support carbon capture and sequestration technology. Producers with negative carbon emissions would be able to seamlessly receive payments for these negative emissions.<sup>10</sup>

In creating an intensity standard that involves both taxes and subsidies, Sweden would need to consider EU state aid rules that place restrictions on subsidies that member states can provide to constituent firms. The EU is revising its state aid guidelines, to take effect in 2021, to ensure that they are consistent with its goals of rapidly transitioning to a green economy yet preserving competition.<sup>11</sup>

<sup>10</sup> See the appendix for an illustration of the effect on costs and marginal carbon price from a combination of EU ETS and a flexible performance standard.

<sup>11</sup> [https://ec.europa.eu/commission/commissioners/2019-2024/vestager/announcements/state-aid-and-green-digital-future\\_en](https://ec.europa.eu/commission/commissioners/2019-2024/vestager/announcements/state-aid-and-green-digital-future_en)

Although these new guidelines are yet to be finalized, a flexible performance standard is consistent with the principles of competition and innovation that motivate state aid rules.

We describe a policy in which the policymaker issues credits based on an intensity standard benchmark and sets the credit price, but the policymaker could merely set an intensity standard and tax or subsidize producers for their emissions above or below the per-unit standard, without issuing credits. However, an advantage of a credit scheme is that it could provide an institutional framework to phase in trading between producers or enable linkage and trading with other sectors or jurisdictions. Tradable performance standards could deliver cost-effectiveness gains by taking advantage of heterogeneous costs and opportunities, allowing the most emission-intensive producers to purchase credits from the least emission-intensive producers, and keeping the revenues and costs within the trading market. Tradability could also eliminate the need for government to subsidize producers, which may help to avoid conflict with the EU prohibitions against providing state aid.<sup>12</sup> Because of the limited number of industrial producers in Sweden, one possibility is to create a trading market between the industrial and transportation sectors. This expanded set of trading entities could increase efficiency and reduce the need for government subsidies, as it would allow more efficient firms to sell credits to less efficient firms. Alternatively, proceeds from the transportation sector carbon tax could support innovation-driving subsidies in the industrial sector. Another option is for Sweden to link with other jurisdictions in the EU to phase in an industrial sector tradable performance standard. Such a standard could establish benchmarks based on an annual rate of progress rather than a uniform level of emissions intensity, to level the playing field between member states with initially relatively higher and lower average emissions intensity of industry.

## Concluding Remarks

In this policy brief, we have discussed the potential to use flexible performance standards by individual ambitious EU member states to strengthen the EU ETS carbon price signal, with a specific focus on the industrial sector. We conclude that flexible performance standards have potential as complementary policies to strengthen carbon pricing and drive innovation. Flexible performance standards combine a carbon price with a production incentive that tempers changes in final product prices, which addresses a key concern of industry regarding carbon pricing.

However, to be able to reap the full efficiency gains from flexible performance standards, countries such as Sweden, with few industrial producers, should explore the possibility of creating a trading market between either the industrial and transportation sectors within the country or a market with other jurisdictions in the EU. If trading is not possible in the short run, a flexible performance standard policy can be implemented *without* it and possibly evolve into a tradable performance standard scheme over time. It should be noted that creating an intensity standard without trade would, in practice, involve both taxes and subsidies, and Sweden would therefore need to consider EU state aid rules that place restrictions on subsidies that member states can provide to constituent firms. However, a flexible performance standard is consistent with the principles of competition and innovation that motivate state aid rules.

Finally, flexible performance standards also have the advantage of being able to support carbon capture and sequestration technology. Producers would be able to seamlessly receive value for negative emissions.

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<sup>12</sup> [https://ec.europa.eu/competition/state\\_aid/legislation/ets\\_en.html](https://ec.europa.eu/competition/state_aid/legislation/ets_en.html)

## Acknowledgements

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## Appendix

We illustrate the complementary incentives for emissions reductions when overlapping an emissions allowance market with a performance standard by describing a firm's decision about the level of emissions reductions under the policies. Define the following terms for the firm's cost minimization problem (subscripts denote derivatives):

$TC$  : total cost

$q$  : quantity produced

$r$  : emissions reductions (abatement)

$c(q, r)$  : production cost;  $c_q > 0, c_r > 0$ ,

$e(q, r)$  : emissions;  $e_q > 0, e_r < 0$

$b$  : benchmark for allocation rate of tradable emissions allowances  $\left(\frac{e}{q}\right)^*$

$s$  : emissions intensity performance standard  $\left(\frac{e}{q}\right)^{**}$

$p^e$  : price of tradable emissions allowances

$p^s$  : price of tradable performance standard credits

$p^q$  : product price

In the emissions allowance market, we assume the firm receives a free allocation calibrated to an emissions intensity benchmark, as applies to industrial firms in the EU ETS. If the firm were regulated only in the emissions allowance market, its total cost function would depend on production costs, including abatement costs, and the cost of complying in the allowance market.

$$TC = c(q, r) + p^e q \left( \frac{e(q, r)}{q} - b \right)$$

The level of emissions reduction that minimizes cost is identified by the first order condition:

$$c_r(q, r) = -p^e e_r(q, r)$$

The familiar result obtained is that the firm minimizes costs by choosing a level of emissions reductions that sets the marginal cost of emissions reductions as equal to the marginal benefit.

If the firm is regulated in an emissions allowance market and under an emissions performance standard, then the total cost function has an additional term.

$$TC = c(q, r) + p^e q \left( \frac{e(q, r)}{q} - b \right) + p^s q \left( \frac{e(q, r)}{q} - s \right)$$

The first order condition in this problem equates the marginal cost of emissions reductions to the sum of benefits under both regulations.

$$c_r(q, r) = -(p^e + p^s) e_r(q, r)$$

Hence, the price of an emissions allowance and the price of a performance standard credit are additive in providing incentives for the firm to reduce emissions.

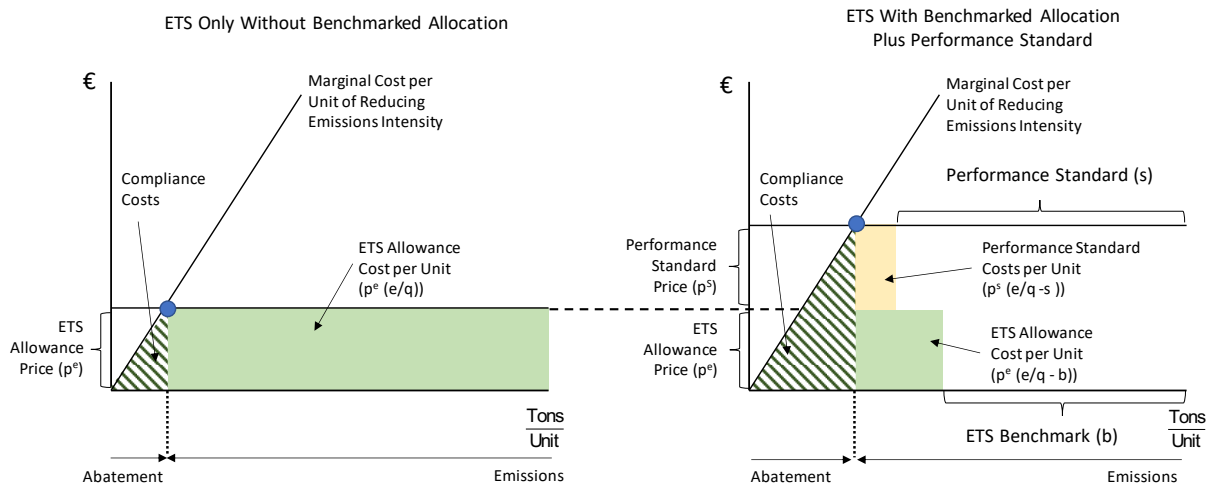
It is important to note that output-based allocation using emissions intensity benchmarks, as in the EU ETS, and a tradable performance standard have the same structure with respect to the costs for an individual firm and the impact on product prices. The firm will maximize profits by equating the marginal cost of production to marginal revenue (the product price), assuming a competitive market.

$$p^q = c_q(q, r) + p^e e_q(q, r) - p^e b + p^s e_q(q, r) - p^s s$$

Allocations according to the emissions intensity benchmark and the tradable performance standard both reduce overall marginal costs because the firm earns valuable allowances and credits with each unit of production. This reduces the change in product prices, which helps to maintain the demand for products regulated domestically and mitigates emissions leakage to unregulated jurisdictions.

The effect on product prices is illustrated in Figure A1. Emissions intensity (tons per unit) is shown on the horizontal axis. Abatement of emissions intensity is measured from the left, and emissions intensity is measured from the right.

**Figure A1.** Benchmarking and flexible performance standards help to preserve industry competitiveness



The left panel shows an emissions trading system without benchmarked allocation. The firm reduces emissions intensity per unit until the marginal cost of doing so equals the ETS allowance price. The crosshatched triangle represents the cost of emissions reductions as the area under the marginal cost curve. The solid rectangle represents the cost burden per unit of production associated with acquiring and surrendering allowances under the ETS. The sum of these values is the total cost of the regulation per unit of production.

The right panel introduces two new features. The first is that the ETS is accompanied with benchmarked allocation. Compared to the left panel, the firm's total production cost per unit is reduced by  $p^e b$ . The second feature is the addition of a flexible performance standard, which we assume might be introduced by Sweden or a group of EU member states and would overlap the ETS. We arbitrarily describe the performance standard as allowing greater emissions intensity (requiring less abatement) than the ETS.

Because of the performance standard overlapping the ETS, the marginal incentive for emissions reductions increases notably in the figure, but the production cost per unit increases by a much lesser amount, helping to preserve the competitiveness of the regulated industry.

## About Mistra Carbon Exit

Mistra Carbon Exit is a research programme that identifies and analyzes the technical, economic and political opportunities and challenges for Sweden to reach the target of net zero greenhouse gas emissions by 2045. We will identify pathways and policies for how Sweden and Swedish companies can become frontrunners in transforming society and industries, providing low carbon products and services while at the same time dressing market risks. This will make Sweden an important international example for other countries to follow.

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