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Carbon Contracts for Differences (CCfDs) in a European context

CLIMATE Strategies

THE GREENS/EFA in the European Parliament

SHORT SUMMARY

Carbon Contracts for Differences (CCfDs) can ensure a **strong and stable carbon price signal that reduces the financing costs and risks of zero-emission investments**, thereby supporting technologies to overcome the valley of death, **leading to their commercialisation and large-scale use**. Making investments in new processes financially attractive **can eliminate the late-mover advantage** of only investing in mature technologies. Like public support for offshore wind power over the last two decades, CCfDs can push the learning curve and help **develop the know-how for an export-oriented European supply industry**.

A first contract similar to a CCfD has been awarded in the Netherlands (SDE++) as a one-sided put-option, and various other Member States are working on national CCfD schemes. On the European level, the proposed revision of the EU ETS Directive introduces CCfD as a novel approach for distributing resources via the Innovation Fund. However, **to quickly design CCfDs on a European level, it is first important to decide on their objectives and scope**. CCfDs with a **fixed strike price** can help reduce investment and financing costs. These benefits can be increased by further reducing policy-related uncertainties, if the **strike price is indexed, for example to** the gap between renewable energy costs for new processes versus fossil fuel costs for competing (conventional) technologies. The award criteria applied to select projects competing for CCfDs may evolve, as CCfDs will initially primarily support **early technology deployment** while shifting gradually to a **risk-hedging instrument for industry-wide technology diffusion**.

If awarding European CCfDs via the Innovation Fund, the **unwelcome correlation between the Innovation Fund budget and the needed CCfD budget** must be addressed. The budget needed to finance long-term CCfDs is higher if the EU ETS market price is lower than expected. **A similar correlation exists if carbon border adjustment mechanism (CBAM) revenues are used to** fund CCfDs. **The European Investment Bank (EIB) could be tasked with smoothing revenues** linked to EU ETS price volatility. Alternatively, the EU could create a **new common fund, similar to the NextGenerationEU Fund**, to finance CCfDs.

However, independently from the funding source, policymakers must be aware that a CCfD is merely an instrument to reduce the exposure of private investors to regulatory risk by creating longer-term certainty on the value of saving emissions. The CCfD does not address technology risks – these remain entirely with the investor. **Risk transfer means that total costs for a CCfD will never be fully predictable beforehand.**

European and national CCfDs for first commercial deployment can co-exist. Both are needed to fund innovations in the hard-to-abate basic material sector and bring technologies to an industrial scale. CCfDs for technology diffusion will only be relevant afterwards, though it must be avoided that CCfDs create unfair competition across national industries. Hence, **a common European approach for CCfDs aimed at technology diffusion is needed so that industries in all Member States have access to sufficient funding**. Clustering different sector and technology options in "maturity pots" can enable competitive CCfDs across various industrial sectors in smaller Member States. Additional funding, similar to the Modernisation Fund, could support lower-income Member States.

Regardless of how CCfDs are implemented, only **technologies that can potentially be operated in a zero-emission economy shall be supported**. At the same time, **projects must be replicable** so that lessons learned can lead to the competitiveness of zero-emission processes in the long run. Measures must be taken to **avoid cross-subsidisation and ensure additionality** if CCfDs are used to fund **green hydrogen production for industrial hydrogen consumers**.

CCfDs are a policy instrument that supports technological change on the production side, including primary production and recycling processes. However, **other policies might be more adequate to support more sustainable and efficient material use along the value chain, crucial for the emergence of a more circular economy**.

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THIS POLICY PAPER HAS BEEN COMMISSIONED BY HENRIKE HAHN, MEMBER OF THE EUROPEAN PARLIAMENT FROM THE GREENS / EFA TO SUPPORT HER LEGISLATIVE WORK, FOCUSSING ON GREEN ECONOMIC AND INDUSTRIAL POLICY.

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INTRODUCTION: GREEN POLICIES IN A CHANGING GEOPOLITICAL LANDSCAPE

The perspectives for industrial policymaking have changed dramatically in the European Union. Enabling the Green Deal and preparing the transition towards a zero-emission society committed to the 1.5-degree target is not the only primary objective anymore. The rapidly changing geopolitical landscape, uncertainty about energy and raw material supply, and turmoil in energy markets have placed supply security at the top of the agenda.

Accelerating European climate ambitions can reduce supply uncertainties and improve European resilience in the long run. The current global political situation seems to foreshadow the changing geopolitics of the energy transformation, as outlined by the International Renewable Energy Agency (IRENA) in their January 2022 report, leading toward a higher degree of energy independence and more competitive global energy markets.[1]

A robust EU policy framework to support the transition toward zero-emission basic material use can improve the resilience of the European economy. Stronger together has been the undertone of national decision making in the COVID-19 pandemic, resulting in joint EU vaccination procurement and European sovereign bonds to fund NextGenerationEU. Russia's invasion of Ukraine has brought the Member States even closer together. A coordinated EU approach to the industrial transition can make EU basic material supply less prone to global market turmoil while aligning the most emission-intensive industrial sectors with zero-emission pathways.[2]

Industrial policy is a Member State matter. Article 173 of the Treaty on the Functioning of the European Union (TFEU) depicts only a coordinating and supporting role for the EU. Hence, various Member States have started developing industry-specific policies to facilitate commercial zero-emission basic material production and use. In this context, publicly funded Carbon Contracts for Differences (CCfDs) are among the most discussed policy options, both on the national and the European level. CCfDs have the potential to provide a strong and reliable carbon price signal, limiting the exposure to volatile global energy and basic material market prices, and reducing investment risks. They can therefore help build a resilient zero-emission European industry by encouraging investments in new circular production and primary processes, while reducing the dependence on fossil energy imports and enabling a renewable hydrogen economy.

In this report, we first explain how CCfDs work, and how they can be designed and then summarise the ongoing policy debate at the national level. We identify the advantages and challenges of CCfD design at the national and European levels and highlight possible pathways towards a robust EU framework for CCfDs.

While this report describes different policy design options for the introduction of CCfDs as a risk sharing instrument between private and public agents in the national and European context, most of our observations also apply for support mechanisms establishing a project specific price floor (put-option). Specific differences between a CCfD and put-option contracts are pointed out in the text.

1. IRENA (2022). // 2. Basic material production account for about two-third of all industrial emissions and is responsible for 14% of EU and 20% of global emissions (Material Economics, 2019; Rissman et al., 2020).

WHAT ARE CARBON CONTRACTS FOR DIFFERENCES

The underlying concept of a CCfD is a long-term delivery contract between the signing parties that reduces the regulatory risks of climate policies. Uncertainty about future CO_2 pricing, concerns regarding the effectiveness of the proposed carbon border adjustment mechanism (CBAM) and reactive policymaking to counter ongoing crises might not provide strong investment incentives for recycling and primary production technologies aligned with the 1.5-degree target.

Instead of taking the investment decision based on expected sales given volatile and unknown EU ETS emission pricing signals, the signing parties agree on a fixed strike price or an alternative pricing mechanism to pay for any delivery for the duration of the contract. **The main advantage for the agent investing and operating the new industrial plant is long-term contractual security**. Long-term contracts are very common, such as for natural gas or electricity, the latter also in the form of Contracts for Differences for electricity supply and generation (CfDs).

A Contract for Difference (CfD) is a special type of long-term delivery contract that has risen to prominence as a mechanism to provide public funding to newly built electricity generation capacity in Europe.[3] National governments run competitive tenders for CfDs. Plant operators (agents) submit bids comprising the strike price they consider necessary to build a project. The projects offering to produce electricity at the lowest strike price are then selected and awarded a contract for difference. The projects subsequently sell the electricity they generated on the market. If the electricity market price is below the strike price, the government pays the difference. If the electricity market price exceeds the strike price, the electricity generator pays back the difference between the spot price and strike price for the volume of electricity produced. It has now been recommended in RePower EU. However, a similar contractual design has been used to finance Flamanville and Hinkley Point C, two nuclear power plants under construction in France and the UK.[4]

A Carbon Contract for Difference (CCfD) applies the CfD concept to emission reductions by industrial projects. In its simplest form, the government or institution agrees with an agent on a fixed effective carbon price[5] to be granted for all emission reductions relative to a conventional technology over a given period, the agent then will receive additional payments if the carbon price is below the strike price (Figure 1).[6]

CCfDs can ensure a strong and stable carbon price signal that reduces the financing costs and risks of zero-emission investments[7], thereby supporting technologies to overcome the valley of death, leading to their commercialisation and competitiveness. Making investments in new processes financially attractive can eliminate the late-mover advantage of only investing in new technology when already proven after the first commercial experience. Like public support for renewable energies such as offshore wind power over the last two decades, they can push the learning curve and help develop the know-how for an export-oriented European supply industry.[8]

CCfDs are a policy option suitable for sectors currently part of the EU ETS and who are facing uncertain future emission allowance prices and free allowance allocation. Since CfDs based on the electricity price are well-established to support renewable generation technologies, the main focus for CCfDs is on industrial emitters, fostering both investments in novel recycling technologies and primary production facilities. Only investments should qualify for CCfD support that are aligned with the long-term emission reduction strategy of the European Union and its Member States. **Only technologies that can potentially be operated in a zero-emission economy shall be supported. At the same time, projects must be replicable** so that lessons learned can lead to the competitiveness of zero-emission processes in the long run.

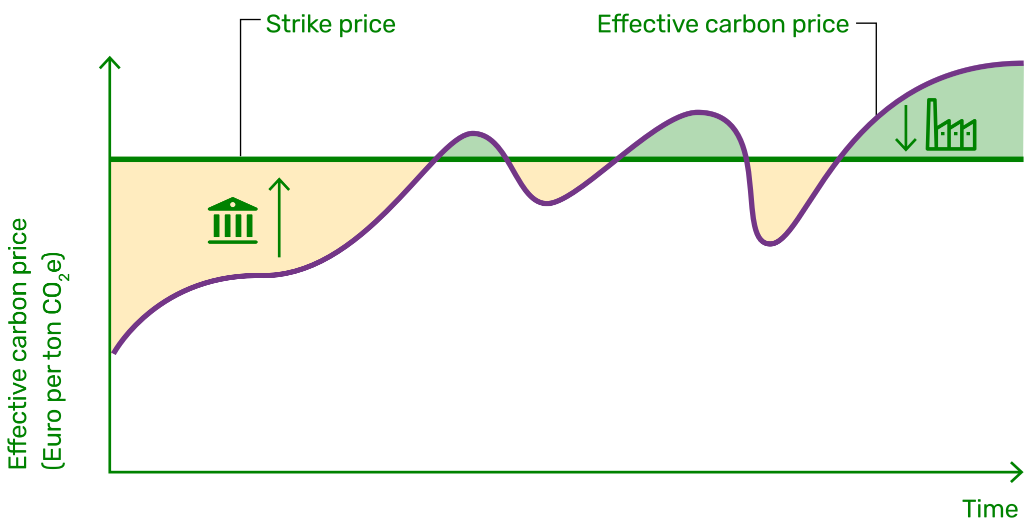
CCfDs can support processes that are not subject to direct emission pricing under the EU ETS. CCfDs always require a carbon price as a reference and would make emitters that are not part of the EU ETS subject to an emission pricing signal. Nonetheless, such exposure might be desirable

3. See for example Szabó et al. (2020). // 4. Chazan and Bream (2012). // 5. Annex A provides a detailed explanation of the effective carbon price and a numerical example for the impact of changing effective carbon prices on CCfD payments. // 6. For a detailed discussion, see Richstein (2017). // 7. Jeddi et al. (2022). // 8. McWilliams and Zachmann (2021).

in specific cases. The objective of the CCfD is to secure a stable revenue stream corresponding to the value of saved emissions from a process compared to a conventional, carbon-intensive, alternative that would typically also be covered by EU ETS, such as producing alternative materials that are direct substitutes for cement consumption or in the case of re- and upcycling processes for basic materials in a more circular economy.[9] As such, a recycling or novel primary production process does not need to be covered by the EU ETS. The CCfD payments would then be securing the incremental costs of the new primary or recycling process. The CCfD is merely a financial instrument which by itself will not imply the coverage of an installation rewarded a CCfD under the EU ETS.[10]

For a more sustainable and efficient material use, it is more complex to define a counterfactual reference value for granting CCfD payments. Enhancing material efficiency, for example, also impacts product requirements and (architectural) design choices for construction and manufacturing. This may be better addressed with ongoing policy initiatives, such as the revision of the Ecodesign Directive and the introduction of the proposed product passport, through Green Public Procurement or effective implementation of a CBAM – either with full auctioning or a Climate Contribution[11]. This illustrates that **CCfDs can only be one building block in a policy package that kick-starts the transition towards sustainable material production and use**.[12]

Figure 1: Basic functioning of a two-sided CCfD.

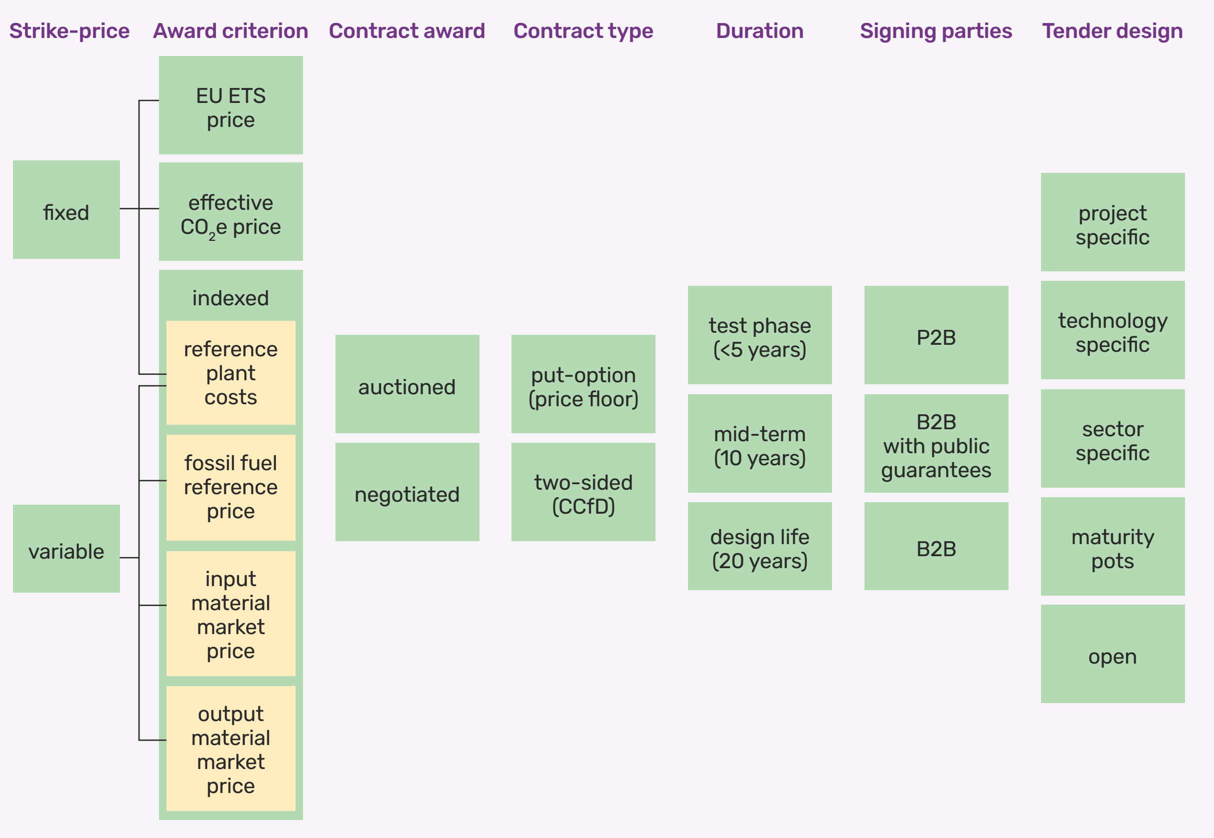


9. In construction, alternative materials that can be used instead of emission-intensive cement, for example ByFusion blocks from plastic recyclate, might require high temperature steam for their production process. Only if subject to the EU ETS, the carbon cost for this potentially emission-intensive production process is correctly reflected in the product price of such alternatives. // 10. Some of the monitoring requirements for EU ETS installations (e.g. quarterly production volume) would also apply to non-EU ETS installations with CCfDs in place. // 11. Neuhoff et al. (2022). // 12. Chiappinelli et al. (2021).

DESIGN ELEMENTS OF A CCFD

Until now, CCfDs are a concept in an early implementation stage.[13] Hence, there is little experience or best practices with CCfD design options. Based on existing academic, policy and government reports, the following potential design elements of CCfDs, as shown in Figure 2, can be identified.

Figure 2: Design elements for contract design



STRIKE-PRICE:

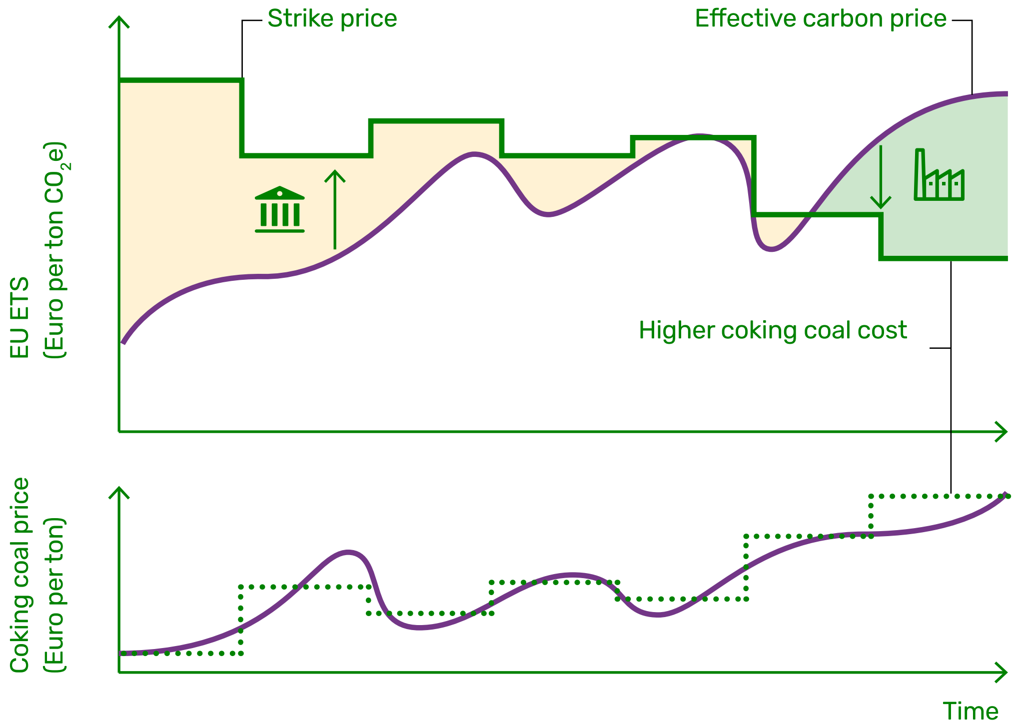
The key element of the CCfD is a strike price to remunerate the emissions savings per tonne of material produced. In its simplest form (Figure 1), a strike price for selling free allowances is fixed to a specific EU ETS price or effective CO_2e price (€ per allowance) between the government and the agent. A fixed strike price provides long-term certainty about the emission price as a cost and revenue position. Hence, it mainly reduces the initial investment risks, financing costs and, as such, capital expenditure (CAPEX) for a project but fails to address most operational costs uncertainties. In order to address operating expenditure (OPEX) uncertainties of novel processes, a CCfD with a variable strike price can establish a carbon pricing signal that is different to the EU ETS.

A variable strike-price mechanism links the carbon emission price for the agent to another variable cost position. The motivation for such indexing is that the competitiveness between new technologies and conventional processes is primarily defined by OPEX differences which do not necessarily correlate with EU ETS price dynamics. Today the market price for energy-intensive basic materials depends on fossil energy and input material costs for highly standardised primary production processes. Steel production costs depends on coal prices, and petrochemical production on natural gas and crude oil prices. In contrast, new processes often (but not always) rely on other input factors with other pricing dynamics, such as electricity or hydrogen. As long as conventionally produced technologies set the national and global market-clearing prices, the difference in these input costs will determine the viability or profitability of less emission-intensive alternatives.

13. See section 4 for current experiences on national level.

AWARD CRITERION:
To ensure potential additional costs are addressed while excessive benefits are avoided, CCfDs strike prices could be indexed to developments of relevant input costs. Such an indexation would be specific to the energy carriers and energy intensity of a sector. In a two-sided CCfD indexed for steel plants, shown in Figure 3, the strike price could be revised based on actual market prices for coking coal on a regular basis (monthly, quarterly or yearly).[14] Here, a higher coking coal market price translates into a reduction of the CCfD strike price. Higher coking coal prices cause higher production costs and increase selling prices for primary steel from emission-intensive conventional processes. Hence, the additional support needed for a novel primary production or recycling process to be competitive with the market price of conventional primary production declines. This example only demonstrates one simplistic design for a variable CCfD. For the case of low-carbon hydrogen production, the UK Department for Business Energy and Industrial Strategy proposes an indexation of natural gas prices and then market prices.[15] Richstein et al. (2021) and Lösch et al. (2022) mention indexation based on coking coal prices and others. The European steel sector calls for an indexation based con conventional reference technologies.[16]

Figure 3: Example of a variable strike price indexed to coking coal prices for steel plants



The functioning of CCfD based on a fixed EU ETS reference price or effective CO2e price criterion depends on the future role of free allowances in the EU ETS. The economics for operating novel processes changes depending on who will be eligible for free allowance allocation. Free allowances based on the current benchmark allocations could only be awarded to conventional processes. However, free allowances could also be awarded to novel processes, by applying the same benchmark allocation used for conventional processes. As such, a zero-emission production process for steel would receive the same free allowances as a conventional blast furnace. The proposed EU ETS revision introduces such a continued free allocation to novel processes beyond 2025.[17] However, potentially eligible installations are not specified further, leaving room

14. See Annex B for a numeric example for indexing a CCfD to coking coal prices. // 15. UK BEIS (2021). // 16. EUROFER (2021).
17. COM(2021) 551 final.

for alternative free allowance award procedures before 2025. Any additional free allowances awarded to new processes are subject to their availability. Given the “cap and trade” system in the EU ETS, the total number of available allowances is restricted by the total emission cap that is decreasing on an annual basis.

CONTRACT AWARD:
Public auctions can be the most economically efficient approach to award CCfDs. Agents that want to install new processes aligned with emission reduction objectives bid on their required strike price. In its role as auctioneer, the government or public institution would simply have to select the lowest bid amongst all projects that qualify and participate in the auction. Prequalification or contract awarding can also be subject to additional non-price criteria. The government can also announce the strike price that is accessible and differentiate the grant level, and the subsidised capacity, by public tendering.[18] Auctions are suitable for standardised and well-defined products. However, negotiations can be superior for technically, legally and financially complex projects for which ex-ante description of the project might be incomplete. Therefore, the priority is to reduce the risk of costly ex-post renegotiations.[19] Novel zero-emission basic material production processes are projects using immature and new technologies. Hence, negotiations might be the better choice for first-of-a-kind CCfDs.[20]

The result of such negotiations might be a mixed pricing mechanism that combines a fixed EU ETS strike price with variable index-based elements. CCfDs can also be awarded after a multi-stage process with several rounds, including a pre-qualification phase. Contracts awarded can be subject to multiple criteria beyond emission reductions and associated costs, such as employment impact, depth of achieved emissions or degree of innovation.

Awarding CCfDs based on expected fixed plant references cost in €/tCO_2[21] makes little sense given the increasing volatility of energy and input material market prices. Most fixed reference costs stated in the literature are based on historically low and relatively stable market scenarios and ignore the dependency between reference abatement costs and energy market prices.

CONTRACT TYPE:
Instead of a symmetric two-sided CCfD, the contract can also be based on a one-sided put-option design (price floor). The most discussed option is a (two-sided) CCfD. The agent receives payments as long as the effective carbon price is below the agreed strike price but has to return any additional revenues obtained when the effective carbon price is higher than the agreed strike price. The put-option establishes the strike price as a minimum price floor. If the effective carbon price is lower than the strike price, the agent receives payments based on the difference to the strike price but doesn’t have to return any additional revenues if the effective carbon price exceeds the strike price.[22] Such additional revenues may result in windfall profits.

DURATION:
While shorter contracts with a duration of up to five years might be preferred for piloting CCfDs, contract durations from 10 years or up to 20 years and more might be more suitable for proving a long-term investment signal to the agent. Industrial processes have a design life that often exceeds 20 years or more. Hence, contract durations of 10 years might be sufficient to cover the plant’s operation until the full phase-out of free allocations in the EU ETS, but might fail to sufficiently address the investment risk for first-of-a-kind projects with an economic design life exceeding 20 years or more. On the other hand, long contract durations create the risk of providing continuous funding to economically inefficient technology options, with the government being locked in contractually to their payment obligations.[23]

18. Richstein (2017). // 19. Bajari et al. (2009). // 20. Richstein et al. (2021). // 21. See, among others reference prices for technologies listed by Sartor and Bataille (2019). // 22. For a discussion of put-option, see Ismer and Neuhoff (2009) and McWilliams and Zachmann (2021). // 23. Jeddi et al. (2022).

SIGNING PARTIES:
As a public support policy, CCfDs will be signed between public institutions and private businesses (P2B). The EU ETS has experienced little forward liquidity and virtually non-existent future markets in the past. However, long-term carbon contracts could potentially also be signed between two private sector stakeholders (B2B), similar to Power Purchase Agreements (PPAs) in the electricity sector. As for PPAs, the government can take the role of facilitators of such contracts by providing financial guarantees.[24]

TENDER DESIGN:
A benefit of CCfDs awarded as a competitive tender could be the avoidance of excessive subsidisation of projects with little contribution to emission reduction targets. One of the biggest challenges is to ensure such a competitive tender design. If project-specific (example: one zero-emission cement plant), technology-specific (example: one chemical recycling facility) or sector-specific (example: CCfD for the aluminium sector), the number of companies that could participate in the tender is reduced to very few highly specialised agents. It would also leave it to the government or public institution to define which options are preferable for reducing industrial emissions, potentially discriminating against other alternatives that could deliver emission reductions at a lower cost. An open tender, allowing any industrial project that can potentially produce basic materials without emitting fossil emissions to participate, might lead hard-to-abate sectors into a carbon lock-in. With an equipment lifetime of thirty years and beyond, sectors with expensive abatement options might invest in conventional technologies instead that remain in operation until 2050 and beyond. If auctioned primarily on a cost-only basis, CCfDs would primarily be awarded to sectors that can implement novel process and recycling designs with a relatively small carbon price premium. In contrast, hard-to-abate industries with high costs for producing zero-emission basic materials would be left without funding opportunities and might reinvest in existing emission-intensive processes instead. In the presence of long-lifetime assets, it is more efficient to start abating simultaneously in several sectors.[25]

Framing CCfDs as commercialisation contracts, Bruegel introduces technological maturity groupings, called "auctioning pots", as an alternative approach to address these shortcomings.[26] The government or public institution groups similarly mature applications across eligible industries into different auction pots. Each auction pot can either be tendered separately or, as suggested by Fabra and Montero (2021), with one auction whereby quota schemes ensure that technologies across all maturity levels obtain funding. Grouping technological maturity into different "pots" must not be limited to auctioning mechanisms only and could also be used by governments or public institutions when awarding CCfDs by negotiation. However, both cases imply that public institutions need to develop a robust framework for categorising and grouping different technology options before the open tender. Pre-qualification of different technology options might require third party verification to reduce the information asymmetry between the public institutions and the industry.[27]

Our overview captures the current state of the debate about potential CCfD design elements. Policymakers, academia, think tanks, and industry continue to work on CCfDs and the implications of policy design options. Developing and incorporating new design options into one or several CCfD design elements will likely not change that **specific CCfD design must be subject to its context and purpose**. A CCfD for enabling first-of-a-kind commercial projects will be designed differently than a CCfD to hedge against long-term carbon price risks for system-wide, basic material production and technology diffusion. Equally, European CCfDs might require a design that is different to national or regional CCfDs.

24. In Spain, national funds are used to back PPAs and the Spanish government has recently called on the European Investment Bank to endorse PPAs (Vélez, 2022). // 25. (Vogt-Schilb et al., 2018). // 26. McWilliams and Zachmann (2021). // 27. Sartor and Bataille (2019).

CCFDS AS PART OF NATIONAL INDUSTRIAL STRATEGIES

Many national governments work on CCfD schemes or are considering them for future application. In the following overview, we first recap available public information about active and planned CCfD schemes in the EU + the UK and then present the insights gained from the discussion with national policymakers and members of the Climate Friendly Materials Platform from Belgium, France, Germany, Hungary, Italy, Poland, Spain, Sweden, and the Netherlands. This overview provides a partial picture of the ongoing policy debate across the various Member States. It shows that **the interest in CCfDs is high, but key questions about their implementation need to be answered both on the national and European levels before the new CCfD schemes can be implemented.**

NETHERLANDS: SDE++

The Stimulation of Sustainable Energy Production and Climate Transition (SDE++) scheme establishes a project specific price floor (put-option) for electricity generation, renewable heat (CHP), renewable gas, low-carbon heat, and low-carbon production processes with an annual budget of 13 billion Euros in 2022.[28] For all but carbon capture and storage technologies, the SDE++ scheme is a put-option based on energy prices. Awarded projects obtain a strike price for renewable energy for a period of 12 or 15 years. On an annual basis, the Ministry of Economic Affairs and Climate Policy calculates the project-specific subsidy paid out to the agents based on the actual amount of energy produced and revenue obtained.

Only in the case of Carbon Capture and Storage (CCS), the SDE++ benchmarks an emission-reduction strike price (€ per ton of CO_2 reduced) instead of an energy strike price. CCS installations receive the difference between emission allowance revenues and the strike price as long as the revenues per ton captured are lower than the strike price. The Porthos project, aiming to permanently store the emissions captured in the Port of Rotterdam offshore, has been awarded SDE++ funding. The final investment decision will be taken in 2022, but the system will not be operational until 2024, and no practical experience with the SDE+ contracts exists until now.[29]

Feedback from industry stakeholders and academia is mixed. Applying two different award mechanisms within one support scheme may have led to unequal funding distribution across different projects. Except for CCS, the scheme awards funds based on energy decarbonisation for all applications, which might exclude promising innovations that can reduce direct and indirect industrial emissions.

GERMANY: KLIMASCHUTZVERTRÄGE

CCfDs for industrial applications were first mentioned in the National Hydrogen Strategy.[30] A corresponding pilot program is currently under development by the Ministry for Economic Affairs and Climate Action.[31] CCfDs are characterised as project-specific instruments to be awarded in a multi-step and multi-criteria competitive award procedure that is open to all eligible industrial sectors. The lowest EU ETS strike prices would only be one out of multiple award criteria that are still to be defined. CCfDs shall be awarded for a contract duration of 10 years and are two-sided, whereby the strike price shall be variable and adjusted yearly, based on energy market prices.

CCfD design is still under development, with funding guidelines to be published soon. However, no concrete timeline for a first national tender has been published so far. Key questions about choices for CCfD elements and the tendering scope remain to be clarified.

UK:

The Department for Business, Energy & Industrial Strategy has published various reports that evaluate CCfDs as an option to support CCS installations and hydrogen production. The latest report advises a variable support scheme based on natural gas and hydrogen market prices. In contrast, a contractual design that reimburses the difference between operational costs

28. RVO (2021). // 29. Porthos (2021). // 30. BMWi (2020). // 31. Initially, the authority to develop a pilot programme was with the Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV ,2021), but was transferred to new Ministry for Economic Affairs and Climate Action (BMWK).

and carbon market revenues is the preferred option for CCS.[32] Both approaches, formulated as put-options, are not primarily targeting the industrial sector and are only theoretical concepts.

OTHER NATIONAL INITIATIVES:
CCfDs have made it to the political discussion across various other EU Member States. In Belgium, CCfDs might be used to fund green hydrogen production processes. However, various questions about the practicality and financing of such a scheme remain unsolved. The availability of revenues from national EU ETS auctions to finance CCfDs will be limited, given that these revenues are mostly allocated already. The Polish mention introducing CCfDs via a dedicated law as one of the legislative actions in their national hydrogen strategy, adopted in November 2021.[33] No further information about concrete plans to develop a national support scheme is available, although the Polish government indicates that it plans to introduce the legislative measures foreseen in the hydrogen strategy in 2022.[34] National policy observers noted that there is a tendency to wait for what is happening on a European level so that they are able to design support schemes aligned with EU state aid rules and potentially design guidelines. France is currently developing measures to meet its 2030 climate targets and national CCfDs are one policy option that is under consideration. However, policymakers highlight the need for aligning CCfD design with other EU countries.

There is a lot of public interest across the other EU Member States, such as Spain and Sweden. CCfDs are considered one potential building block for industrial policymaking. One of the main barriers in Sweden and other smaller Member States is the lack of competition if CCfDs are awarded nationally. While funding is available, governments want to avoid uncompetitive tenders if national sectors only consist of a very small number of players. In Spain, there is a particular interest in how CCfDs could support the build-up of a hydrogen economy. The question of whether or not the increased budget of the Innovation Fund would be sufficient to fund first-mover installations across the EU Member States was raised. Plans by the Italian government to support the development of a hydrogen economy could be backed by CCfDs. However, CCfDs as a potential new policy instrument have not emerged in the wider Italian policy debate. In Hungary, both at an industrial and institutional level, the interest in CCfDs is high. However, an active role of the government seems very unlikely, so stakeholders favouring CCfDs seek a European solution.

32. UK BEIS (2021b, 2021a). // 33. Ministerstwo Klimatu i Środowiska (2021). // 34. Tretyn (2022).

Governments calling for CCfDs make a strong commitment to an industrial policy that can foster the transition toward a zero-emission economy. National CCfDs are not only a policy instrument to support the commercialisation of low emission technologies but also a public pledge for the future importance of emission pricing.[35]

Ambitious national industrial policies are crucial to achieving European climate targets. According to the Treaty (TFEU Article 173), the EU only has a coordinative and supportive role in industrial policymaking. As long as they comply with EU state aid rules, **Member states maintain autonomy and authority to design individual national industrial policies**, while the EU has not pushed for a stronger interpretation of its mandate.[36]

National industrial policies need to be evaluated in the context of the EU Internal Market, namely a competitive and fair single market (TFEU Articles 4, 26 and 114). In the face of the transition towards zero-emission, it must therefore be ensured that national policies are not in conflict with this principle leading to indiscriminate advantage for national industries. All Member States must be able to offer their industries a fair opportunity to transition. Hence, the main **challenge to national CCfD design is supporting zero-emission basic material production in a national context without leading to unfair competition in the EU single market.**

From a legal perspective, CCfDs could be considered a form of subsidy. National governments are likely to pay out more to the agents than they receive while a transfer of risk from the agent to the national government takes place. **Technically, CCfDs are state aid.**

State aid is allowed as long as it helps facilitate the development of certain economic activities within the European Union (TFEU Article 107). This exception is used to support investments in environmental protection and emission reductions. In this context, the revised State Aid Guidelines published in February 2022[37] allow for such measures in specific cases, explicitly mentioning CCfDs, given their contribution to the legally binding 2030 target for energy and climate. The authority to evaluate these trade-offs between competitiveness and climate objectives remains with the Commission and is decided on a case-by-case basis. Here, aid must comply with a revised incentive assessment that evaluates the subsidy's impact on competition and trade based on the necessity of aid, appropriateness, proportionality, and transparency of the measure.[38] A competitive award procedure is not a requirement, though, heavily encouraged by the proportionality assessment. **National CCfD tenders designed for a technology, project or even sectoral level may struggle to safeguard competitiveness due to the small number of agents within the national context**. Hence, national tender designs should include mechanisms that avoid overfunding, for example, via the use of counterfactual impact evaluation.

Any national CCfD schemes would require a positive assessment from the Commission. **Competitive tendering procedures for first-mover installations with a clear focus on supporting innovations will most likely be approved by the Commission**. The Dutch SDE++ scheme, for example, was approved in December 2020, given that it contributes to the EU environmental objectives without unduly distorting competition.[39]

CCfDs would first be used for technology deployment and, later on, could support technology diffusion. In the case of technology diffusion, the **implications of national CCfDs are in stark contrast to national CfD schemes that support the diffusion of renewable electricity generation technologies.**[40] Basic material production relies on large scale industrial installations. Due to the limited scalability of processes, national industries often consist of a very small number of players.[41] Hence, it will be difficult to ensure competitiveness in national CCfD tenders for technology diffusion. In contrast, renewable energy generation with solar PV, wind turbines,

35. Gerres and Linares (2020). // 36. EPRS (2019). // 37. See, Communication 2202/ C 80/01. // 38. EC (2022). // 39. See Case number SA.53525 in the State Aid register. // 40. In 2014, the Commission approved UK´s CfD scheme for offshore wind support (SA.36196), Portugal´s approach of combining CfDs with guarantees was approved in 2016 (SA.41694) and Greece´s latest CfD scheme in 2021 (SA.60064). // 41. See the SFI Global Cement Databse (McCarten et al., 2021a) and SFI Global Steel and Iron Database (McCarten et al., 2021b) for the numbers of steel and cement plants in each EU Member State.

or biomass is highly scalable, allowing for competitive national CfD tenders with a large number of participants achieving economically optimal bidding.

Especially considering long-term emission reduction targets, **national CCfDs could also encourage the build-up of zero-emission industry in regions with suboptimal access to renewable energy sources or CCS employment options** required to operate these processes. Today´s basic material production centres developed due to their historically favourable access to raw materials, such as iron or mineral deposits, as well as energy sources like coal and natural gas. However, these regions are often far away from renewable energy production centres requiring additional investments in transport infrastructure. National CCfDs to replace existing industrial facilities one-to-one with new technologies might lead to the geographical lock-in to historic industrial production centres, weakening the renewable-pull effect to build zero-emission production facilities in regions (and the Member States) with abundant access to renewable energy sources.[42]

National CCfDs can be an important building block for industrial policies that lay the groundwork for the transition towards a more circular and zero-emission basic material production. However, **continuous support for sector-wide technology adoption on a national level can only occur if not in conflict with the fundamental principles of the EU internal market.**

42. See, Samadi et al. (2021) for a detailed definition of the renewable pull-effect.

The European Union must ensure that CCfDs guide a fair transition of the basic material sector. The level of EU involvement can take various forms, ranging from regulatory guidance for national CCfD designs compliant to state aid rules, to the awarding of genuine EU CCfDs.

The European Commission proposes that CCfDs could be used as an award mechanism for the Innovation Fund.[43] Similar to ongoing national initiatives, the focus would be on new technology projects that comply with the established award criteria of the Innovation Fund. Given estimated funding needs of 28.9 Billion for industrial reinvestments in Europe until 2025[44] and the available Innovation Fund budget of 25 Billion until 2030[45], financing beyond first-mover applications is unlikely. However, the political discussion to significantly increase the available budget is ongoing. As of today, the budget available to the Innovation Fund stems from the auctioning of EU ETS allowances. However, the budget needed to finance long-term CCfDs is higher if the EU ETS market price is lower than expected. Hence, **there is an unwelcome correlation between the Innovation Fund budget and CCfD budget needs**. Additionally, under current legislation, innovation funding is limited to 10 years. It can only cover 60% of the occurring operational costs, therefore limiting the potential role of CCfDs in a reform of the Innovation Fund. **Such EU CCfDs could only complement national efforts to support the first commercialisation of technologies** that can deliver recycled or primary basic materials aligned with zero-emission pathways.

Other options for EU CCfDs would require the identification of new funding sources or the redistribution of the expected revenue stream. Depending on its final design, the introduction of a CBAM, as planned by the European Union, may provide sufficient funding.[46] Given that the level of available CBAM income also correlates with EU ETS market prices, this approach would run into the same issues about budgetary certainty as the Innovation Fund. McWilliams and Zachmann (2021) suggest that the European Investment Bank (EIB) could be tasked with smoothing revenues linked to EU ETS price volatility, lending to the CCfD fund when prices are lower than expected and being paid back in instances with high EU ETS prices. However, this risk would be similar across all CCfDs in the EIB portfolio. This implies that the EIB could only secure a revenue stream corresponding to the observed minimum carbon price, which might result in insufficient funding for an EIB smoothing mechanism. If a general minimum price floor on the EU ETS was established, a minimum revenue stream for CCfD funding would be guaranteed. The EIB would only address the mismatch between an indexed strike price (e.g. based on fossil fuel, material or reference plant costs) and EU ETS market prices.

EU CCfDs, as a stand-alone risk hedging instrument for supporting technology diffusion, can also complement other financing instruments of the EIB that currently include grants and loans. Like the NextGenerationEU fund, which is partially managed by the EIB, a new mandate would be needed to award such EU CCfDs. Industry-wide availability of such CCfDs for large-scale sector transformation risks may jeopardise the ability of the EU ETS to provide adequate market price signals. In 2018, industry alone accounted for about 35% of verified EU ETS emissions.[47] Hence, an industry-wide application of CCfDs could decouple these industries from market price incentives. In this context, **various stakeholders have raised concerns that the potential market dynamics caused by CCfDs on the EU ETS are not well understood.[48]** However, such claims have little ground as long as CCfDs are only granted to new, zero-emission installations to foster first commercial deployment, or awarded at scale but in line with carbon price expectations.

Independently from the described funding sources, policymakers on the national and European levels must be aware that the CCfD is a policy instrument that transfers the regulatory risks related to the economic feasibility of novel technologies from the private agent to a public stakeholder. **This risk transfer means that total costs for a CCfD for the public will never be fully predictable beforehand.**

43. COM(2021) 551 final. // 44. Chiappinelli et al. (2021). // 45. EC (2021). // 46. Neuhoff et al. (2021). // 47. Marcu et al. (2019). // 48. See, EEX (2021) and Marcu and Fernandez (2022).

First national CCfD-like contracts have already been signed in the Netherlands and are under development in Germany, while several other Member States work on national support schemes. **A European approach to CCfDs will be second to national initiatives. Therefore, the EU will have to develop its own position concerning the compatibility of national CCfD schemes with state aid rules and internal market principles.** This position must also cover potential national CCfD schemes that aim to fund industry-wide technology diffusion and must therefore be evaluated differently than the already approved SDE++ scheme.

By **developing an EU framework for competitive national CCfDs supporting technology diffusion**, the European Union could facilitate national schemes that strengthen the internal market. Over the next years, there is a window of opportunity for the Parliament and the Commission to gain experience from national CCfD schemes, study the implications of different CCfD design elements and evaluate the impact of industry-wide CCfDs on the EU ETS. Experts from academia, industry, governmental and non-governmental organisations have suggested various approaches that could facilitate CCfDs aimed at technology diffusion:

Allowing multilateral CCfDs awarded under an enhanced cooperation procedure by at least nine EU Member States could address some of the concerns faced by national CCfDs.[49] A joint cross-border CCfD award can allow smaller Member States to ensure a competitive tender design.

Comparability is key for evaluating bids in a CCfD award procedure. Therefore, it must be explored how third-party verification and benchmarking across different projects can ensure that different national CCfD schemes are not in conflict with the principles of the internal market while establishing eligibility criteria for CCfD tenders. Similar to the role of the Agency for the Cooperation of Energy Regulators (ACER) for electricity and gas markets, the European Union could establish a mandate that tasks one of its institutions or the ACER with monitoring and comparing the outcomes of national CCfD schemes.

Clustering different technology options in "maturity pots" requires a sound methodology and a better understanding of how within-sector cross-technology[50] or broad cross-sector cross-technology clustering[51] can help improve the competitiveness of CCfD schemes on a national level. Ideally, a European mechanism based on common maturity pots and award criteria can ensure competitive national tenders compliant with internal market rules.

Countries with less national funding available might require additional support to finance the transition of their national industries via CCfDs. Further boosting the solidarity mechanisms in the EU ETS, such as the Modernisation Fund, and matching them with strong climate conditionalities and exclusion criteria can provide additional revenues.[52] These revenues could then support CCfD schemes that accelerate technology diffusion in the ten lower-income EU Member States.

49. See, TFEU Article 20 and McWilliams and Zachmann (2021). // 50. Richstein et al. (2021). // 51. Sartor and Bataille (2019) // 52. Vangenechten and Lehne (2021).

CCfDs are a public support mechanism that can potentially facilitate investments in new technologies. This general assessment is shared by many stakeholders on the national and European level and motivates public institutions, such as the European Parliament, to explore its practical implementation.

There are no standardised CCfD contracts and award mechanisms. Depending on its purpose, policymakers can make various design choices when developing specific CCfD schemes. CCfDs are no all-purpose tool and have various limitations. They primarily enable investments and operations of new technologies that allow for primary production and recycling processes aligned with zero-emission objectives. However, they do little to change how materials are used in final products. Hence, CCfDs are an incomplete policy tool that does not equally support all potential solutions for a zero-emission economy. **CCfDs cannot replace but only complement effective EU ETS carbon price signals for emission-intensive basic material production.** The business case for more efficient material use in final products and enhanced sorting and upcycling relies on a strong carbon price signal for emission-intensive primary production processes. CCfDs should be seen as an important part of a comprehensive policy package to support the transition towards a zero-emission and more circular economy.[53]

In the European context, two main questions are decisive about the future role of CCfDs. First, whether CCfDs should be implemented on the national or European level. Second, whether CCfDs should primarily be used to foster first commercial deployment or also support technology diffusion (Figure 4).

Figure 4: Opportunities and risks for national and EU level CCfDs aimed at technology development and diffusion

	Technology deployment		Technology diffusion	
	Opportunities	Risks	Opportunities	Risks
National level	☑ Serves the objective of innovation upscaling ☑ Schemes already under development ☑ SDE++ CCfD approved by DG Competition	⍰ Competitive tenders difficult in small member states ⍰ Creating more than first mover advantages on a national level	☑ Continuity of national CCfD schemes ☑ Harmonized EU approach could allow for tenders compliant with state aid rules	⍰ Can lead to unfair competition on the EU internal market ⍰ Favors industries in rich member states ⍰ Environmentally and macroeconomically non-optimal industry allocation
EU level	☑ Budget available via Innovation Fund ☑ Open to projects in all member states ☑ Fosters cross-border collaboration	⍰ Current award criteria limit duration and funding per project ⍰ Correlation between EU ETS price and available funding	☑ Fair framework conditions for industry across all member states ☑ Good fit for common Single Market ☑ Compatibility to EU ETS with single European carbon price	⍰ Reduces the autonomy of member states for industrial policy ⍰ Requires a robust EU award mechanism ⍰ Relies on robust EU funding income

53. Neuhoff et al. (2019).

National CCfD schemes that support technology deployment have already been implemented in the Netherlands and are currently being drafted in Germany. These schemes have a clear emphasis on innovation upscaling, which is crucial to bring the technologies to market readiness and provide the groundwork for a sector-wide transition in the European Union. They create a first-mover advantage for national players in the bigger EU Member States since smaller Member States will struggle to design competitive tendering procedures. **As long as CCfDs are still a type of innovation funding to develop the know-how for these processes in Europe, the EU should encourage the Member States to award national CCfDs.**

Existing European support policies, namely the EU Innovation Fund, can be used to award CCfDs to the first commercial installations across all EU Member States. As complementary to national support policies, **Innovation Fund CCfDs don't address the difficulties of smaller and low-income Member States to award their own CCfD contracts. Novel European approaches to award CCfDs for technology development require additional funding streams and mandates.** Lengthy legislative processes mean that additional funding might only be available when the first commercial installations are already in place. Independently from the funding source, policymakers must be aware that the CCfD is a policy instrument that transfers the risks related to the economic feasibility of novel technologies from the private agent to a public stakeholder. This risk transfer means that total costs for a CCfD will never be fully predictable beforehand.

A European approach will be crucial if CCfDs will also be necessary to support technology diffusion. If funding is used to scale-up industry-wide adoption rather than support innovations, national CCfDs might struggle to comply with state aid rules. **The transition from CCfDs for innovation funding to technology diffusion must be accompanied by a common European approach to CCfDs design.**

National CCfDs must comply with state aid rules and internal market principles. **The EU must be prepared to provide guidance on designing national tenders or developing its own CCfD scheme that is complementary to the EU ETS.** There is a window of opportunity for the EU to lay the groundwork for a European approach to CCfDs over the next years, evaluate the impact of large-scale CCfD employment on the EU ETS, and design CCfD design guidelines based on the lessons learned at the national level.

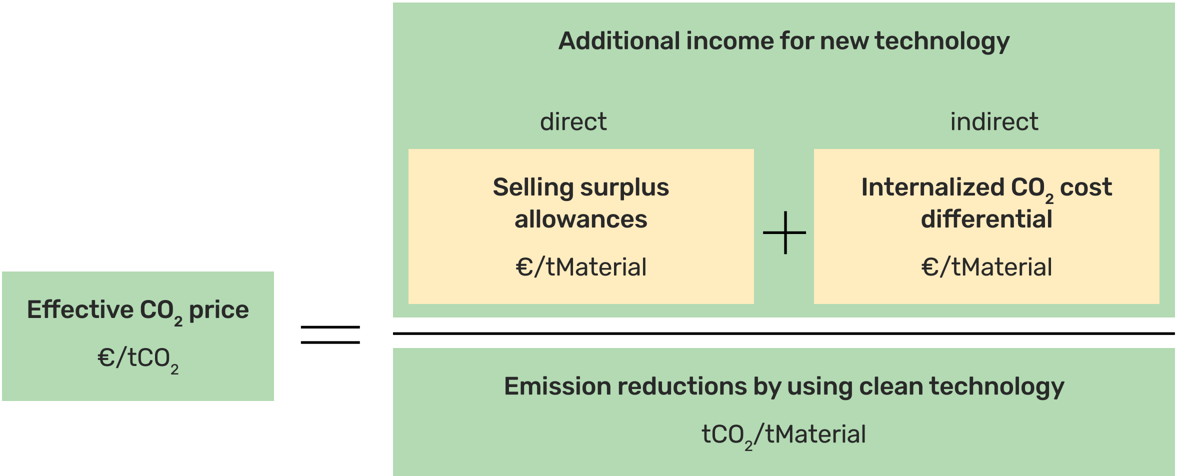
CCfDs are only one building block of an integrated policy backing the transition towards a zero-emission basic material consumption in Europe aligned with the 1.5-degree target. Consumption oriented policies that incentivise sustainable material use need to be supported by supply-oriented measures facilitating the build-up of a zero-emission industry. By financing first-mover installations and reducing the investment risks, CCfDs can strengthen the business model of new primary production and recycling processes, however without impacting end-consumer prices and the resulting incentives for efficient use of materials. CCfDs are complementary to existing supply-side policies, such as innovation funding, the EU ETS, the Industrial Emissions, Renewable Energy and Energy Efficiency Directives, while relying on consumption-oriented policies, such as the revised Ecodesign Directive, to move towards a circular economy.

CCfDs would accelerate the transition from fossil fuel-intensive industrial production processes to an industrial sector consuming primarily renewable energy. **As part of a targeted industrial policy, CCfDs can help the European Union and their Member States to make future industrial energy consumption less dependent on fossil fuel imports by diversifying the energy mix, making itresilient against external shocks.** Developing a common European approach for CCfDs is crucial for the diffusion of zero-emission technologies by the national industries across all EU Member States.

ANNEX A: EFFECTIVE CARBON PRICING

The effective carbon price received per ton of carbon reduced by a new technology would be the sum of the income obtained from selling surplus free allowances (if any) and the CO_2-related cost differential with the conventional technology (Figure 5). This price differential would only appear if the European market prices for basic materials have internalised, totally or partially, the cost of carbon.

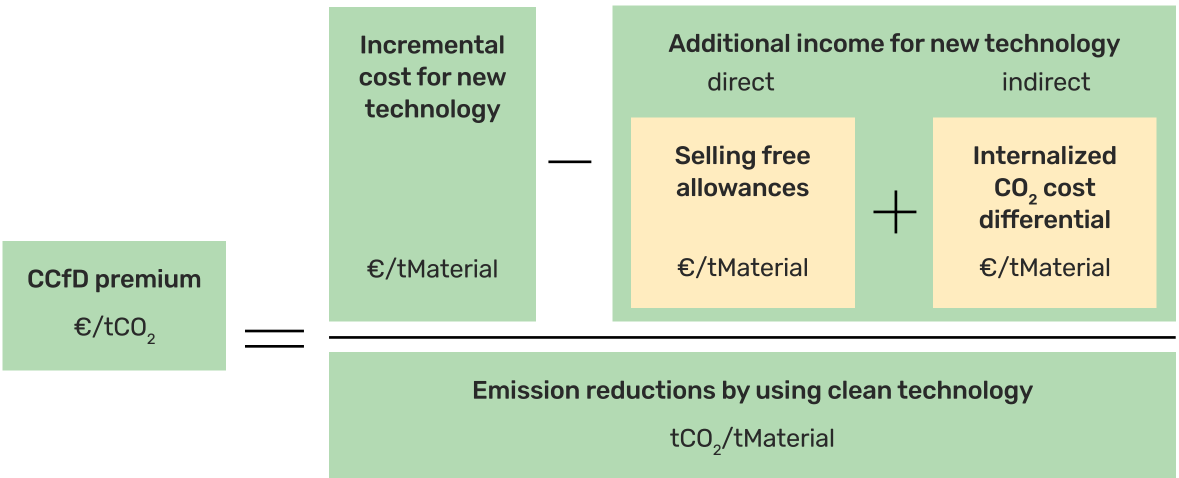
Figure 5: Semantic overview of the effective CO_2 price for new technologies. Based on Lösch et al. (2022)



This effective carbon price is therefore based on the price at which surplus allowances may be sold, and on the price differential in turn based on internalised carbon prices. In the current situation, both prices are set by the EU ETS. The CCfD is a risk-hedging instrument that ensures a stable carbon price (by balancing the difference between the strike price and the ETS price[54]), and hence, a stable effective carbon price for new technologies.

In addition, the CCfD strike price may include a premium over the expected market carbon price. This "CCfD premium" would cover the additional revenues to be received by the new technology, beyond the effective carbon price, to become competitive. They should cover the difference between the incremental cost of the new technology and the effective carbon price (Figure 6).

Figure 6: Semantic overview of CCfD premiums based on effective CO_2 pricing. Based on Lösch et al. (2022)



54. See Figure 2 in Vogl et al. (2021).

ANNEX A: EFFECTIVE CARBON PRICING

The following example demonstrates the effective carbon pricing formation for a new zero-emission steel plant. Two subcases are considered: either the currently used primary steel plants emitting 1.6 t CO_2/tMaterial sets the marginal market price (subcase a) or a plant that emits at the emission allowance benchmark of 1.3 tCO_2/tMaterial sets the marginal price (subcase b). A new technology can provide zero-emission steel (0 tCO_2/tMaterial) at a combined incremental capital and operational cost of 100 €/tMaterial produced. If the CO_2 emission allowance price is 50 €/tCO_2, the effective CO_2 price "benefit" for the new technology would be as follows (Table 1):

Table 1: Effective CO_2 prices for three sample cases (t/M = t/Material)

	Case 1a	Case 1b	Case 2a	Case 2b	Case 3a	Case 3b
The market has internalised CO_2 prices:	no	no	yes	yes	yes	yes
1.3 tCO_2/tM free allowances:[55]	yes	yes	yes	yes	no	no
Emissions of plant setting marginal price:	1.6 tCO_2/tM	1.3 tCO_2/tM	1.6 tCO_2/tM	1.3 tCO_2/tM	1.6 tCO_2/tM	1.3 tCO_2/tM
Direct EU ETS income for new technology	50 €/tCO_2 * 1.3 tCO_2/tM = 65 €/tM				0 €/tM	
CO_2 cost-related price differential to conventional technology	0 €/tM		50 €/tCO_2 * (1.6-1.3) tCO_2/tM = 15 €/tM	50 €/tCO_2 * (1.3-1.3) tCO_2/tM = 0 t/Mt	50 €/tCO_2 * 1.6 tCO_2/tM = 80 €/tM	50 €/tCO_2 * 1.3 tCO_2/tM = 65 t/M
Total CO_2 pricing income for new technology:	65€/tM	65€/tM	80€/tM	65€/tM	80€/tM	65€/tM
Emission reduction by using new technology	1.6 tCO_2/tM	1.3 tCO_2/tM	1.6 tCO_2/tM	1.3 tCO_2/tM	1.6 tCO_2/tM	1.3 tCO_2/tM
Effective CO_2 price	40.6 €/tCO_2	50 €/tCO_2	50 €/tCO_2	50 €/tCO_2	50 €/tCO_2	50 €/tCO_2

For all cases, the effective CO_2 price is lower than the incremental cost of abating each tCO_2 with the new net-zero emission technology. The abatement cost of the new technology is:
- Subcase a: 100 €/tMaterial / 1.6 tCO_2/t = 62.50 €/tCO_2
- Subcase b: 100 €/tMaterial / 1.3 tCO_2/t = 76.92 €/tCO_2

As such, the CCfD premium required to cover the incremental cost of abating each tCO_2 with the new net-zero emission technology is higher in subcase b, given that the steel plant setting the marginal price is less emission-intensive than in subcase a, while the incremental cost to produce with the new net-zero technology (100 €/tMaterial) remains the same. For subcase a, the premium is lower if the market internalizes the CO_2 cost differential in cases 2a and 3a, than for case 1a for which no cost-related price differential between new and conventional technology exists (Table 2).

55. For this example, free allowances are awarded to all (both conventional and new technology) production processes.

Table 2: Total payments from effective CO_2 pricing and the CCfD premium for new zero-emission technology

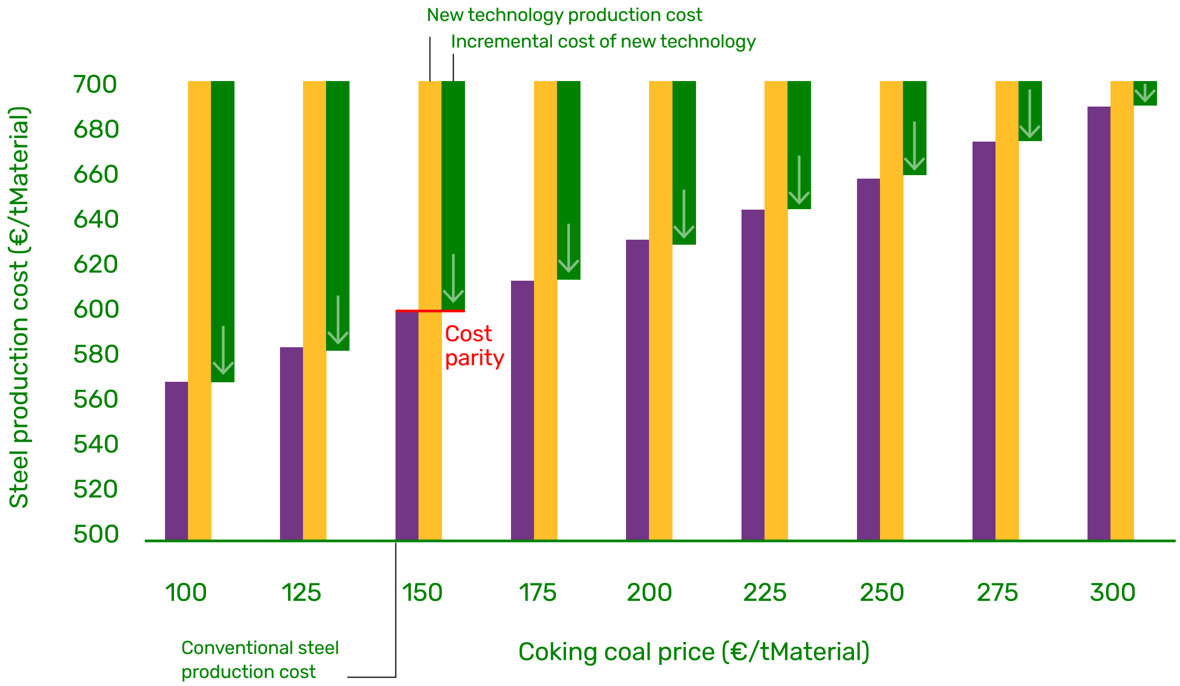
	Case 1a	Case 2a and 3a	Cases 1b , 2b and 3b
Effective CO_2 price	40.63 €/tCO_2	50.00 €/tCO_2	50.00 €/tCO_2
CCfD premium	21.87 €/tCO_2	12.50 €/tCO_2	26.92 €/tCO_2
Total payments	**62.50 €/tCO_2**	**62.50 €/tCO_2**	**76.92 €/tCO_2**

Note that effective CO_2 prices would be the same for all cases but in case 1a. As soon as markets fully internalise CO_2 prices, free allowances don't impact the competition between new and conventional technologies. However, to fully internalise the CO_2 price on the European steel market, all domestic steel and imports must be subject to CO_2 pricing, e.g. by an effective CBAM.

The following highly simplified example shows how a CCfD can be indexed to market prices for coking coal. The underlying assumption for this example is that for each ton of primary steel produced with a conventional blast furnace 600 kg of coking coal is required, and the new technology, e.g. hydrogen-base steel making, does not require coking coal. For this example, it is further assumed that the incremental cost of abating each tCO_2 with the new net-zero emission technology is 100 €/tMaterial[56] and the conventional plant has a total production cost of 600 €/tMaterial if the market price for coking coal is 150 €/tMaterial.[57] Without a CO_2 pricing mechanism in place, the incremental cost for producing with a zero-emission plant changes significantly with fluctuating market prices for coking coal. Figure 7 shows how the incremental cost of producing with the new technology increases by about 30% if the market price for coking coal declines by about 30%. However, the incremental costs diminish by 90% if the price for coking coal triples. Note, between January 2016 and July 2020, Australian prime hard coking coal (FOB) has been traded at a range between 76.1 $/tMaterial and 311.3 $/tMaterial.[58]

This example ignores that the new technology might also face fluctuating energy costs when obtaining zero-emission energy carriers. These observations also don´t apply to CCS technology, for which coking coal would be used in the zero-emission process. In the latter case, an indexed CCfD to market prices for coking coal would not make sense.

Figure 7: Impact of coking coal prices on the incremental production cost for zero-emission steel



In an indexed CCfD the premium would depend on the market price for coking coal and the effective CO_2 price for the new technology. The following example shows how the premium of an indexed CCfD would vary given changing effective CO_2 prices. With reference to the different cases presented in Annex A, it is assumed that the market price reflects a cost differential due to CO_2 prices.

Table 3 shows the variation of conventional steel production costs given a fixed price of 50 €/tCO_2 and a declining coking coal price. The CO_2 price increases the conventional steel production costs by 16 €/tMaterial at a coking coal price of 150 €/tMaterial compared to the corresponding

56. For this example, we assume that for the new zero-emission technology energy costs are constant. In the case of hydrogen-based steelmaking a long-term delivery contract for green hydrogen could establish such operational cost stability. // 57. Assumptions loosely based on coking coal market data provided by the IEA (2021) and steel prices provided by the OECD (2019). // 58. (IEA, 2021).

production costs without CO_2 pricing mechanisms in place as shown in Figure 7. If the emissions of the plant setting the marginal price are 1.6 tCO_2/tMaterial (subcase a in Annex A), then the production cost difference of 20 €/tMaterial between the conventional and new technology requires a CCfD premium of 12.50 €/tCO_2 (compare Case 2a and 3a in Table 2, Annex A). However, declining coking coal prices reduce the production cost for conventional steel, so that if maintaining a CO_2 price of 50 €/tCO_2, the required CCfD premium would have to be four times higher if the coking coal cost declines to 50€/tMaterial.

Table 3: Impact of declining coking coal cost on (indexed) CCfD premium

CO2 price €/tCO_2	**Coking coal cost €/tMaterial**	**Conventional steel cost €/tMaterial**	**New technology steel cost €/tMaterial**	**CCfD premium €/tCO_2**
50	150	680	700	12.50
50	125	665	700	21.88
50	100	650	700	31.25
50	75	635	700	40.63
50	50	620	700	50.00

As shown in Table 4, an increase in effective CO_2 prices combined with a decrease in coking coal prices could affect the incremental cost of a new technology in such way that it could potentially balance out the variations in the CCfD premium. Higher CO_2 prices increase the production cost of conventional processes while declining coking coal prices reduce their costs at the same time. The resulting CCfD premiums decline by only 2.5 €/tCO_2 or about 5% if CO_2 prices increase from 10 to 50€/tCO_2 while coking coal prices decline from 150 to 50 €/tMaterial at the same time.

Table 4: Impact of declining coking coal cost and increasing CO_2 prices on (indexed) CCfD premium

CO2 price €/tCO_2	**Coking coal cost €/tMaterial**	**Conventional steel cost €/tMaterial**	**New technology steel cost €/tMaterial**	**CCfD premium €/tCO_2**
10	150	616	700	52.50
20	125	617	700	51.88
30	100	618	700	51.25
40	75	619	700	50.63
50	50	620	700	50.00

In contrast, an increase in both effective CO_2 prices and coking coal leads to the reduction of the CCfD premium (Table 5). The premium of 52.5 €/tCO_2 at a CO_2 price of 10€/tCO_2 and coking coal price of 150 €/tCO_2 becomes almost zero with an effective CO_2 price near 40 €/tCO_2 and a 50% increase in coking coal prices. Negative premiums indicate that in a two-sided CCfD the new technology operator would have to pay back the benefits obtained from an effective CO_2 price that is higher than the incremental cost of the new technology. In case of a put-option contract, no cash flows from the new technology plant operator back to the public institution would occur.

Table 5: Impact of increasing coking coal cost and increasing CO_2 prices on (indexed) CCfD premium

CO_2 price €/tCO_2	Coking coal cost €/tMaterial	Conventional steel cost €/tMaterial	New technology steel cost €/tMaterial	CCfD premium €/tCO_2
10	150	616	700	52.50
20	175	647	700	33.13
30	200	678	700	13.75
40	225	709	700	-5.63
50	250	740	700	-25.00

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