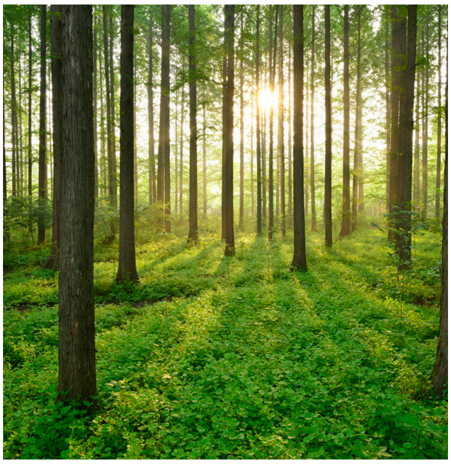
CONTRACTS FOR DIFFERENCE (CFD) IN THE SWEDISH ELECTRICITY MARKET

REPORT 2024:991



FUTURE ELECTRICITY MARKET DESIGN

Energiforsk

Contracts for Difference (CfD) in the Swedish Electricity Market

EA ENERGY ANALYSES

ISBN 978-91-7673-991-4 | © Energiforsk February 2024

Energiforsk AB | Phone: 08-677 25 30 | E-mail: kontakt@energiforsk.se | www.energiforsk.se

Foreword

The electricity market design is intensely discussed, EU-wide as well as domestically in Sweden. Contracts for Difference (CfD) is one of the more prominent tools promoted to support invest in new electricity generation capacity. This report maps and discuss the design choices involved.

Ea Energy Analyses has in its mapping of CfDs discussed the different design choices such as strike price, technology neutrality and location specifications. This report provides overall guidance on how a technological neutral CfD tender could be designed.

This is a project under the umbrella of the future electricity market design program (FemD) in Energiforsk.

Summary

In March 2023, the European Union (EU) proposed a reform of the electricity market design. This reform includes rules for support of non-fossil fuel power generation based on two-way Contracts for Differences (CfDs). The EU market design proposal allows some flexibility to each member state in terms of the design of the CfDs, provided that CfDs are designed to maintain incentives for power generation facilities to operate efficiently and participate actively in the electricity markets.

CfDs provide a revenue guarantee for low carbon generators, enhancing long-term stability for both producers and consumers. However, this might disrupt market dynamics by reducing market incentives. To address this issue, ENTSO-E and other entities propose decoupling CfD remuneration from injection, such as in financial CfDs or capability-based CfDs, where the support is independent of the actual plant output. From a government's perspective, CfDs involve considerable uncertainty about the annual costs (benefits) of the CfD support scheme as this depends on the level of market prices. To address this issue, certain CfD schemes incorporate measures such as a cap on cumulative payments. An alternative proposal suggests using both a cap and floor price instead of a single strike price. In this setup, the floor price ensures generators a minimum revenue, while the cap prevents windfall profits.

Defining the CfD's objective is crucial before designing the mechanism, as its design influences policy targets. Design choices, like geographic and technological specifics, should align with these objectives. The Tidö agreement advocates for technology neutrality, fostering fairness among fossil-free technologies. This report provides overall guidance on how a technological neutral CfD tender could be designed. CfDs may also be applied to procure capacity for specific locations, such as a particular site for a nuclear power plant or an offshore wind farm, or a broader geographic area, like a price zone. Applied in this way, CfDs provide a tool to ensure a better balance between demand and supply, as a means to realize the Swedish government's goal of harmonizing wholesale power prices across Sweden.

Svenska Kraftnät, the Swedish TSO, has expressed concerns that the energy-only market may not be able to provide the necessary level of security of supply. As a result, it advocates for a market-wide capacity mechanism. CfDs should be primarily limited to low carbon, non-fossil fuel technologies that have low and stable operational costs, and typically do not provide flexibility to the electricity system. However, it is pertinent to discuss whether the application of CfDs to stimulate investments in baseload technologies, such as nuclear energy and offshore wind power, could potentially reduce the need for a market-wide capacity mechanism. Moreover, both CfDs and capacity markets serve a common purpose by contributing to the protection of consumers from the effects of high electricity prices. To avoid double compensation of generators, it is crucial to assess how capacity contracted under a CfD is remunerated in a capacity market.

Keywords

CfD, electricity market reform, risk-sharing, revenue guarantee

Sammanfattning

I mars 2023 föreslog Europeiska unionen (EU) en reform av elmarknadens utformning. Denna reform omfattar regler för stöd till kraftproduktion som inte är fossila bränslen de så kallade tvåvägskontrakt för differenser (CfD), eller i svensk översättning marginalkontrakt. Förslaget till utformning av EU:s marknad ger varje medlemsland viss flexibilitet när det gäller utformningen av CFD-kontrakten, förutsatt att CFD-kontrakten är utformade för att upprätthålla incitamenten för kraftproduktionsanläggningar att fungera effektivt och delta aktivt på elmarknaderna.

CfD-kontrakt ger en intäktsgaranti för koldioxidsnåla producenter, vilket ökar den långsiktiga stabiliteten för både producenter och konsumenter. Detta kan dock störa marknadens dynamik genom att minska marknadsincitamenten. För att komma till rätta med detta problem föreslår Entso-E och andra aktörer att CfD-ersättningen frikopplas från tillskottet, t.ex. i finansiella CfD-kontrakt eller kapacitetsbaserade CfD-kontrakt, där stödet är oberoende av anläggningens faktiska produktion.
Ur ett regeringsperspektiv innebär CFD-kontrakt en betydande osäkerhet om de årliga kostnaderna (fördelarna) för CfD-stödsystemet, eftersom detta beror på marknadsprisernas nivå. För att ta itu med detta problem innehåller vissa CfD-system åtgärder såsom ett tak för ackumulerade betalningar. Ett alternativt förslag är att man använder både ett tak och ett minimipris i stället för ett enda lösenpris. I den här konfigurationen garanterar minimipriset producenterna en minimiintäkt, medan taket förhindrar oväntade vinster.

Det är mycket viktigt att fastställa målet för CFD-kontraktet innan mekanismen utformas, eftersom dess utformning påverkar de politiska målen. Designval, liksom geografiska och tekniska detaljer, bör anpassas till dessa mål. Tidöavtalet förespråkar teknikneutralitet och främjar rättvisa mellan fossilfria tekniker. Denna rapport ger övergripande vägledning om hur ett teknikneutralt CfD-anbud skulle kunna utformas. CfD-kontrakt kan också användas för att anskaffa kapacitet för specifika platser, t.ex. en viss plats för ett kärnkraftverk eller en havsbaserad vindkraftpark, eller ett större geografiskt område, t.ex. ett prisområde. Tillämpat på detta sätt ger CfD:er ett verktyg för att säkerställa en bättre balans mellan efterfrågan och utbud, som ett sätt att förverkliga den svenska regeringens mål att harmonisera grossistpriserna på el i hela Sverige.

Svenska Kraftnät har uttryckt oro för att marknaden kanske inte kommer att kunna ge en nödvändig nivå av försörjningstrygghet. Som ett resultat av detta förespråkar de en marknadsomfattande kapacitetsmekanism. CfD-kontrakt bör i första hand begränsas till koldioxidsnål teknik som inte bygger på fossila bränslen och som har låga och stabila driftskostnader och som vanligtvis inte ger elsystemet flexibilitet. Det är dock relevant att diskutera huruvida tillämpningen av CFD-kontrakt för att stimulera investeringar i baslastteknik, såsom kärnkraft och havsbaserad vindkraft, potentiellt skulle kunna minska behovet av en marknadsomfattande kapacitetsmekanism. Dessutom tjänar både CFD-kontrakt och kapacitetsmarknader ett gemensamt syfte genom att bidra till att skydda konsumenterna från effekterna av höga elpriser. För att undvika dubbel kompensation till producenter är det mycket viktigt att bedöma hur kapacitet som avtalats inom ramen för ett CFD-kontrakt ersätts på en kapacitetsmarknad.

List of content

1 Introduction

The EU has proposed a reform of the electricity market design in March 2023, which includes rules for power production based on two-way Contracts for Difference. The reform aims to make the electricity market more flexible, secure and integrated. Two-way CfDs are contracts signed between a public entity and a power generating facility operator that provide at the same time a minimum remuneration protection for the electricity company, when the market price is below a strike price, and a limit to excess remuneration, when the market price is above the strike price.

The aim of CfD is to reduce price volatility, shield consumers from price spikes, accelerate the deployment of renewables and nuclear energy and improve industrial competitiveness. Contracts for Difference will most likely become the main tool for direct government price support schemes for new investments in renewables and nuclear power within the EU.

The Council had reached an agreement on the reform in October 2023 and in December 2023 a provisional agreement the new rules were approved by both the Council and the European Parliament. To make it EU law the directive needs to be endorsed and formally adopted by both institutions.

The aim of this study is to investigate how CfDs could be designed to serve the objectives of Swedish climate and energy policies while being compliant with the new electricity market reform.

The primary purpose of this study is to provide a basic understanding of the current EU CfD proposal and how it could be implemented to the benefit of the Swedish energy market. This includes an understanding of the Swedish challenges and an analysis of various aspects of CfD contracts, such as the choice of counterparty, duration of contracts, technologies, or capabilities to be rewarded, and more. The study will also explore how contracts can be designed, whether there should be a localization signal, how revenue per kWh is determined, and how situations with negative prices can be handled.

The report covers three main themes:

1. Firstly, we discuss the specific challenges in Sweden, including necessary investments in both variable renewables (wind and solar) and in firm power.
2. Secondly, we conduct an analysis of various aspects of CfD contracts. This involves research into existing practises, EU communication as well as literature and studies on the subject.
3. Thirdly we present recommendations and options for how to apply and design CfDs in a Swedish context.

As part of the project, we have held a workshop and collected viewpoints of selected stakeholders in the Swedish market, including representatives from energy companies, regarding the development of the Swedish energy sector, as well as their thoughts on the role, challenges and opportunities of CfDs in a Swedish context. These viewpoints were integrated in the report.

2 Status of the Swedish Electricity System

Sweden is currently divided into four electricity price areas: Malmö (SE4), Stockholm (SE3), Sundsvall (SE2) and Luleå (SE1). The Swedish electricity market is part of the Nordic power market Nord Pool, which has a spot market for trading electricity per hour for delivery the next day. Most of the trade per hour takes place on Nord Pool, while a smaller portion is made directly between electricity generators and electricity suppliers.

2.1.1 Shifts in Swedish Electricity Prices

Historically, electricity prices in Sweden have been relatively uniform across the northern and southern regions. However, recent years have witnessed a significant shift in this trend, with prices in central and southern Sweden reaching unprecedented levels, while those in the north have remained modest.

The reasons behind this disparity are likely twofold:

1. *Increasing Power Generation Costs in Continental Europe*: Southern Sweden is electrically connected to continental Europe, which relies heavily on thermal generators for power production. The costs of operating these generators have risen due to increasing prices of CO2 quotas in the EU Emissions Trading Scheme and escalating fuel prices, the latter being a consequence of Russia's invasion of Ukraine.

2. *Expansion of Wind Power and Closure of Nuclear Units in Sweden*: Sweden has seen a substantial expansion of wind power, particularly in the northern regions where permissions for new wind power projects have been more readily granted. Concurrently, nuclear units in central Sweden (Ringhals 1 and 2 and Oskarshamn 1 and 2), have been decommissioned.

These developments have led to bottlenecks in the internal Swedish electricity grid, especially between SE 2 and SE3, and also between SE3 and SE4, resulting again in huge price differences across the country (see Figure 2-1).

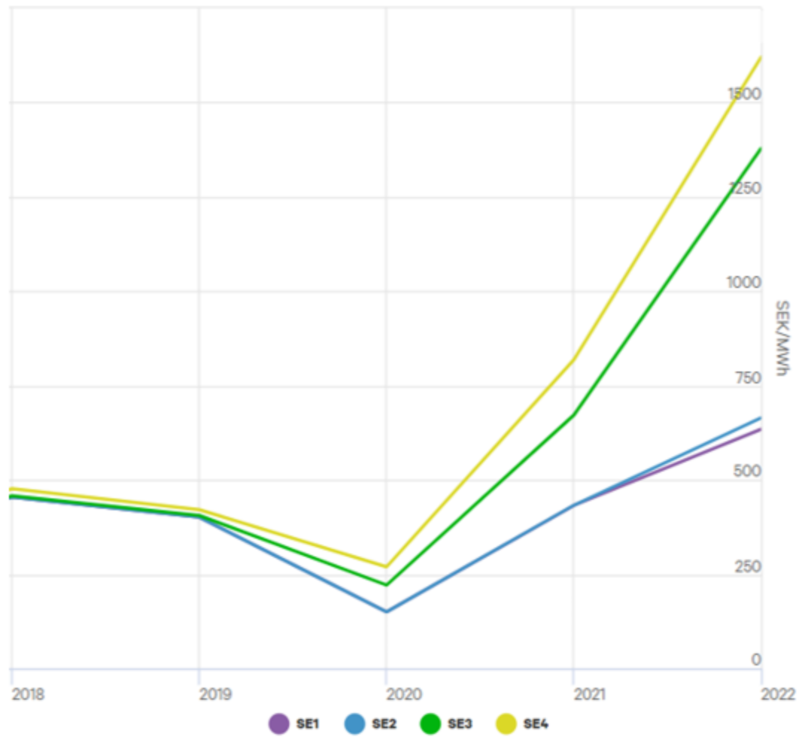


Figure 2-1 Annual average of electricity in the day/ahead market for the Swedish price zones in recent years.
Source: Energimyndigheten (2023)

2.1.2 The Tidö agreement

The Tidö agreement, signed in 2022 by Sweden Democrats, Moderate Party, Christian Democrats and Liberals for appointing Ulf Kristersson as Prime Minister of Sweden, has significant implications for energy and climate legislation. The Agreement aims to "re-establish" a functioning electricity system with increased electricity generation and low electricity prices and to facilitate an effective climate transition. It redefines the policy goal to a 100% fossil-free energy system rather than 100% renewable energy system and requires planning for a forecasted electricity demand of at least 300 terawatt hours in 2045. The key proposals of the agreement include:

- Strengthened conditions for nuclear power investments with SEK 400 billion credit guarantees. Owners should be compensated if plants are forced to close and investigations should be made into restarting Ringhals 1 and 2. Nuclear power plants should be allowed at new sites and the state-owned electricity company Vattenfall should start planning for nuclear plants at Ringhals and other appropriate locations. Changes to the Environmental Code are proposed to facilitate new nuclear power plants, introduce faster permit processes, and reduce application fees.
- Previous plan to subsidise offshore wind power grid connections is halted, maintaining the principle that those who connect to the grid should bear the costs. The starting point should be that all types of production bear their own costs.

- Investigation of an electricity market reform, with the aim of proposing rules that ensure all types of power have equivalent regulations. This includes a system where necessary ancillary services for a well-functioning electricity system are priced, and those power types that provide such services are compensated, primarily through payments from producers who cannot provide the same support services.
- Another goal is to make Sweden a unified electricity price area by better balancing electricity production and electricity use in different parts of Sweden. This means that the expansion of exporting electric cables should be paused until the price differences between the price areas have decreased significantly.

2.1.3 Existing support schemes

Since 2003, Sweden has utilized an electricity certificate system to augment its renewable electricity supply, thereby aiding in the achievement of renewable energy targets. These electricity certificates are primarily traded between market participants who have quota obligations and those eligible for electricity certificates. A common market for these certificates has been established between Sweden and Norway since 1 January 2012. According to the International Energy Agency (IEA)[1], this system has not only delivered the expected volumes but has also proven to be relatively cost-efficient, especially when compared to countries that have implemented feed-in tariffs. The certificate scheme's 2030 energy target of generating 46 TWh of new renewable energy was achieved as early as March 2021, leading to a significant drop in prices within the scheme.

In 2021, the Swedish government decided that new production facilities commissioned after the end of 2021 would not be eligible for electricity certificates. As a result, the deployment of renewable energy in recent years has occurred on market terms, without any subsidies from the government or electricity consumers. Long-term Power Purchase Agreements (PPAs) are becoming increasingly important for renewable energy developers and electricity consumers, typically industrial companies, as they provide a reliable and cost-effective way to finance renewable energy projects. These agreements allow electricity producers to sell their output to energy utilities or corporate end-users over a fixed period, providing renewable energy generators with a steady source of income in highly volatile power markets. For buyers, they offer not only a credible way to green their own operations but also more certainty in their business planning.

Unlike many other Northern European countries, Sweden has not promoted the deployment offshore wind-power through auctions or similar support schemes. Less than 200 MW of offshore wind capacity is in operation and though 18 offshore wind farms are either consented or have applied for consent, none are currently in the build phase[2].

[1] IEA 2019: Energy policies of IEA countries, Sweden 2019 review.
[2] According to https://www.4coffshore.com/windfarms/sweden/

2.1.4 Capacity support scheme

Sweden and the rest of the Nordic countries have traditionally indicated a preference for energy-only markets. In Sweden the energy-only market has been supplemented by a strategic reserve of 562 MW, which expires in March 2025. Historically contracted volumes have been significantly higher, close to 2 GW in 2010[1]. The current strategic reserve is provided by Karlshamnsverket in SE4.

The strategic reserve should be located in either SE3 or SE4 and may only be activated after all the commercial bids on the market are used.

In June 2019, a new EU regulation on the internal electricity market entered into force. It defines capacity mechanism' as a temporary measure to ensure the achievement of the necessary level of resource adequacy and introduces harmonized EU methodologies for procuring and designing capacity mechanisms. According to the draft electricity market directive, the Commission should come forward with proposals with a view to streamlining and simplifying the process for assessing capacity mechanisms. This indicates that the EU approval procedures for new capacity mechanism might be softened.

Svenska Kraftnät projects that by 2027, an additional capacity of between 2,500 and 3,000 MW will be required in southern Sweden to maintain the reliability standard of a maximum of one hour of power shortage per year[3]. To ensure resource adequacy in the electricity market, Svenska Kraftnät anticipates the need for a capacity mechanism post-2025. Furthermore, Svenska Kraftnät asserts that a strategic reserve will not be sufficient for meeting Sweden's long-term needs. Instead, they advocate for the introduction of a market-wide capacity market in Sweden. Svenska Kraftnät also suggests that the capacity market should be structured in a way that emphasizes the transmission constraints in the grid, thereby ensuring higher capacity payments in areas with deficits, i.e. in Southern Sweden.

2.2 ENERGY OUTLOOK FOR SWEDEN

A recent study by Energimyndigheten[4] explored different scenarios for the future of Sweden's energy system and found that major changes are expected regardless of the scenario . The main drivers of these changes are:

- The shift from fossil fuels to **electricity as the main energy carrier**, which will reduce greenhouse gas emissions and increase energy efficiency.
- The **increased demand for electricity** due to the processing of raw materials, such as producing more carbon free steel from Swedish iron and establishing new industries, such as electrofuels and battery factories.

4. The **production of hydrogen through electrolysis**, which can be used as a fuel or a feedstock for various sectors.

[3] Svenska Kraftnät, 2023. A future capacity mechanism to ensure resource adequacy in the electricity market.
https://www.svk.se/siteassets/om-oss/rapporter/2023/a-future-capacity-mechanism-to-ensure-resource-adequacy-in-the-electricity-market.pdf

[4] Energimyndigheten 2023, Scenarier över Sveriges energisystem 2023 -med fokus på elektrifieringen 2050.

Important changes predicted in the energy system are:

- A significant decrease (70-77%) in the use of fossil fuels like oil, coal, and natural gas by 2050.
- By 2040, when nuclear power is considered, fossil-free electricity production could account for 99–99.5% of Sweden's total electricity.
- By 2050, the transport sector's energy consumption is projected to drop to 49-54 TWh, with most passenger cars being electric.
- The goal to reduce energy intensity by 50% by 2030 (compared to 2005) is projected to fall short in all scenarios, with a reduction of 41–43% expected.

In the most progressive scenario (Higher electrification) total electricity demand increases from 134 TWh in 2020 to 349 TWh in 2050, and according to the report demand may increase sharply already in the short-term. To meet this large demand for electricity, substantial investment in new electricity production capacity and electricity grids are needed, as well as a reinvestment in the existing electricity system. According to Energimyndigheten, a strong electrification is not possible without good conditions for all fossil-free power types.

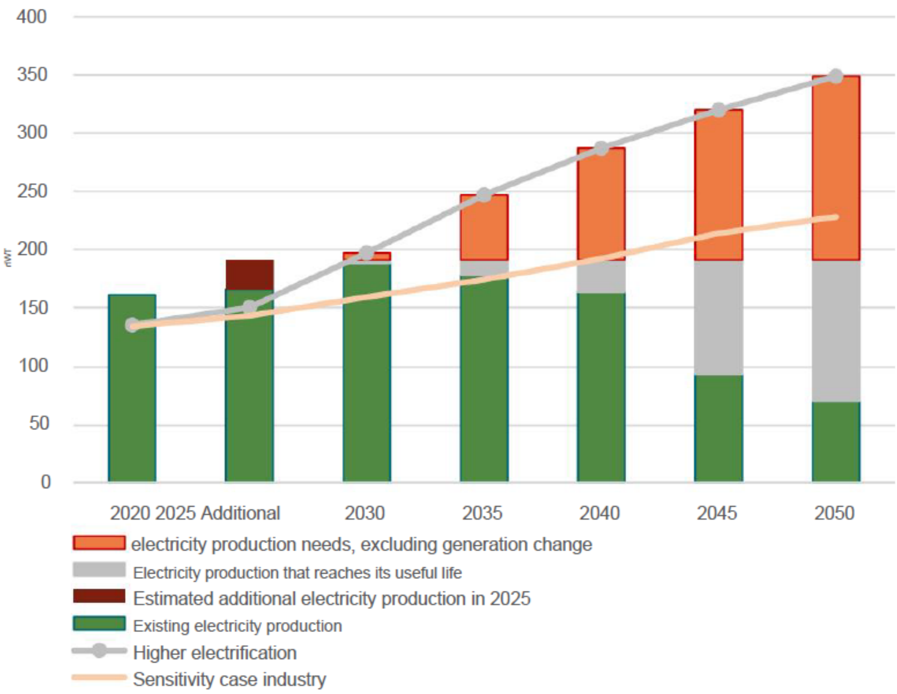


Figure 2-2: Increase in electricity demand by 2050 (lines) in comparison with existing electricity production and the need for new generation capacity (columns). The outcome room shows the difference between different scenarios (Higher electrification and Sensitivity case industry).

Source: Energimyndigheten (2023)

2.3 SWEDISH ENERGY OUTLOOK AND THE POTENTIAL ROLE OF CFD

Sweden's energy system faces several intricate challenges,

- ➔ Electricity demand is expected to increase markedly, potentially two or threefold, to ensure the needed decarbonization of the energy system. A large portion of the new electricity demand is expected to be used for hydrogen production.
- ➔ Onshore wind and ground mounted solar power have been developed on market terms but are likely not sufficient to cover the projected increase in electricity demand. It is not clear if the energy-only market is able to drive investment in nuclear power and offshore wind power.
  - Following, EU electricity market reform, CfDs should be applied, if the Swedish government wishes to directly support renewables or nuclear power.
- ➔ The Swedish government wants to ensure a level playing field between different fossil-free energy sources. At the same time the current government indicates a preference for nuclear energy and proves amongst others, SEK 400 billion of credit guarantees for nuclear facilities.
  - Following the EU electricity market reform, CfDs may be applied to support specific technologies, but contracts for CfD may also be structured to allow for competition between specific technologies.
- ➔ The TSO, Svenska Kraftnät, asserts that the energy-only market, will not be able to provide the necessary level of security of supply, and calls for a market-wide capacity mechanism.
  - Procurement of renewables and nuclear power capacity through CfD will improve the security of supply.
  - However, according the to the EU new electricity market regulation, support through CfDs should be limited to low carbon, non-fossil fuel technologies, with low and stable operational costs and to technologies which typically do not provide flexibility to the electricity system. In other words, CfD are not supposed to be used to support traditional peak power capacity or storage technologies, which market-wide capacity mechanism primarily aim to support.
- ➔ The Swedish government seeks to harmonise prices between price areas, eventually **paving the way for one unified electricity price zone.**
  - CfD may be applied to procure capacity for either specific locations, such as a particular site for a nuclear power plant or an offshore wind farm, or a broader geographic area, like a price zone. In other words, a CfD may provide a powerful tool to ensure a better balance between demand and supply, as a means to harmonise wholesale power prices across Sweden.

3 Contracts for Difference (CfDs)

The Paris Agreement, the EU's Green Deal, and Sweden's national decarbonization pathway are collectively shifting the focus toward non-fossil fuel generators as the fundamental pillars of the energy system. However, renewable energy generators and nuclear power plants require high investment costs and have low variable costs, which exposes them to revenue risks at the electricity market. To provide long-term support and de-risk the investment in clean energy resources, different tools are available, such as Feed-in Tariffs (FiT), Guarantee of Origin (GOs), Power Purchase Agreements (PPAs) and Contracts for Difference (CfDs). While CfDs are often seen as a subsidy, Beiter et al. (2023) argue that the role of CfDs is to serve as a risk management tool by establishing a marketplace for electricity provision at consistent, extended-term rates that are essential for financing renewable energy projects due to the scarcity of hedging alternatives in current markets. With the process of the EU electricity market reform in 2023, CfDs have moved into the spotlight.

CfDs provide low carbon generators with a fixed minimum price for their generation. In the electricity market, CfDs are usually traded between a generator and a public entity, based on a strike price that is determined in an auction. The beneficiary is then entitled to receive the difference between the fixed strike price and a reference price, for example the market price per unit of output. CfDs support investors in hedging against price fluctuations and thus finance low carbon solutions and other features that make the power system more reliable and resilient but may not be adequately rewarded by the regular market, such as energy, firm and flexible capacity, inertia and reactive power. An example of a CfD mechanism is shown in Figure 3-1[5].

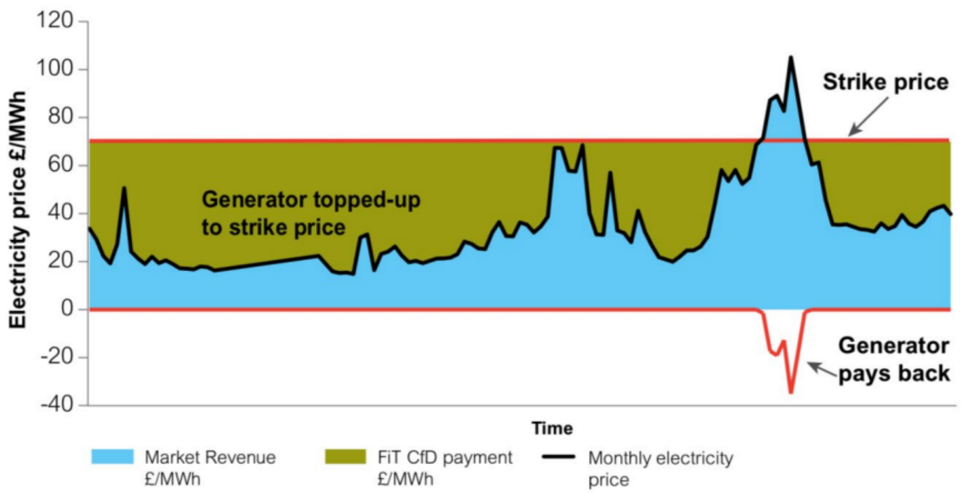


Figure 3-1 CfD Mechanism.

Source: UK Gov. (2011/2019)

The objective of CfDs is to enhance investment stability by promoting a long-term minimum revenue guarantee for producers, and thus supporting the growth of low carbon generation. This helps lower the cost of capital for generation investors by mitigating price risks, subsequently reducing levelized energy costs. In the electricity

5 https://assets.publishing.service.gov.uk/media/627e3c4be90e0721b3675f3d/CfD_evaluation_phase_1_final_report.pdf

system, CfDs are considered a government support scheme – similar to feed-in-tariffs (FiT). The aim is to design CfDs in a way that they provide financial stability to non-fossil fuel investments while keeping electricity market distortions as minimal as possible. Thus, an efficient CfD serves as a financial hedge while also preserving the electricity market signals that ensure optimal utilization and investment incentives, encompassing initial investment, operation, retrofit, repowering, and maintenance, without dampening the price signal (Schlecht et al., 2022). Moreover, compared to feed-in-premiums or feed-in-tariffs, CfDs can mitigate political risk for investors by ensuring that the state is legally bound by the contracts. This prevents government intervention in case of a change in leadership, safeguarding investors' interests.

3.1 CFDS IN THE EU ELECTRICITY MARKET REFORM

CfDs are a common tool to support the growth of wind and solar energy and have been used for more than 50% of the global offshore wind supply (Beiter et al., 2023) and to support nuclear energy in among other the UK. In the EU, before the current reform, CfDs were a tool permitted under the Guidelines on State Aid for Climate, Environmental Protection, and Energy (European Commission, 2022). With the electricity market reform proposed by the European Commission on 14 March 2023, a renewed focus is put on CfDs. The proposal stipulates that direct price support schemes allocated to new low-carbon, non-fossil fuel electricity generation facilities should be in the form of CfDs (European Commission, 2023).

Specifically, any direct price support schemes for new investments in the following technologies should take place as two-way CfDs:

(a) wind energy;
(b) solar energy;
(c) geothermal energy;
(d) hydropower without reservoir;
(e) nuclear energy;

The proposal further defines that the support through CfDs should be limited to technologies with low operational costs and technologies, which 'typically do not provide flexibility to the electricity system'. CfDs should take the form of a 'two-way CfD' - In addition to the revenue guarantee (minimum price), the strike price(s) provide a limit to excess remuneration (Council of the European Union, 2023b). The reform aims to ensure that non-fossil power producers receive a minimum return on their investment, while preventing public-supported energy producers from profiting from high market prices. By providing a minimum guarantee, CfDs lower the financial risk of renewable energy developers and thus reduce the cost of capital. The European Commission expects that this will create 'a virtuous circle where stable revenues lower costs and boost demand for renewable energy' (European Commission, 2023). According to the proposal, the money returned by the producers will be used to support all electricity consumers and reduce the impact of high prices.

On 13 December 2023 the last trilogue was held between the European Parliament and the Council and a provi-sional agreement on the electricity market reform was found. The agreement keeps CfDs mandatory for direct price support schemes of new power-generating facilities, while broadening the scope of directing government support to 'equivalent schemes with the same effects' (Council of the European Union, 2023a).

And while the focus of the support is on new capacity, the agreement also includes the option to use CfDs for 'new investments aimed at substantially repowering existing power generation facilities, or at substantially increasing their capacity or prolonging their lifetime' . There is a three-year transitional period for the restructuring of direct government support schemes and a five-year transition period for offshore hybrid assets connected to two or more bidding zones.

The EU expects that in periods of high energy prices, two-way CfDs will provide an additional source of income for the Member States. According to the reform proposal, the generated revenues should be directed towards supporting the final customers, finance the costs of the direct price support schemes or investments to reduce the costs for final customers (Council of the European Union, 2023a). These allocations serve to heighten the efficiency, decarbonization efforts, and overall security of the power system.

This report does not address the question of financing a CfD scheme or the non-distortive distribution of funds to consumers, as these aspects are considered beyond the scope of the study. However, it is worth noting that the European Commission's proposal highlights the potential of two-way CfDs as a means for Member States to generate supplementary revenue during periods of heightened energy costs. To address the impact of high electricity prices on consumers' expenses, Member States are urged to ensure that funds obtained from producers' revenues are fairly distributed to all categories of electricity consumers—ranging from households to small enterprises and industrial users—based on their individual usage patterns. The reform seeks to maintain incentives for consumers to reduce or shift their consumption according to the price signals. Crucially, Member States are tasked with implementing this redistribution without compromising the equitable competition among suppliers operating within the electricity market (European Commission, 2023).

3.2 EU CFD DESIGN REQUIREMENTS

The aim of CfDs is to provide long-term financial stability in a way that does not interfere with the market signals, but rather encourages the producers to act according to them.

The EU electricity market reform does not stipulate a certain design for two-ways CfDs but specifies certain criteria that CfDs should be designed to:

- (a) preserve incentives for the generating facility to operate and participate efficiently in the electricity markets, in particular to reflect market circumstances.
- (b) prevent any distortive effect of the support scheme on the operation, dispatch and maintenance decisions of the generating facility or on bidding behaviour in day-ahead, intraday, ancillary services and balancing markets;
- (c) ensure that the level of the minimum remuneration protection and of the upward limit to excess remuneration are aligned with the cost of the new investment, the market revenues, to guarantee the long-term economic viability of the power generating facility while avoiding overcompensation;
- (d) avoid undue distortions to competition and trade in the internal market, notably by determining remuneration amounts through a competitive bidding process that is open, clear, transparent, and non- discriminatory. In cases where no competitive bidding process can be conducted, contracts for difference or

equivalent schemes with the same effects – and the applicable strike prices - shall be designed to ensure that the distribution of revenues to undertakings does not create undue distortions to competition and trade in the internal market;
- (e) avoid distortions to competition and trade in the internal market resulting from the distribution of revenues to undertakings;
- (f) include penalty clauses applicable in the case of undue unilateral early termination of the contract (Council of the European Union, 2023a).

According to the proposed directive, two-way contracts for difference could vary in duration and could include inter alia injection-based contracts for difference with one or several strike prices or a floor price (Council of the European Union, 2023a). To ensure that the contract obligations are fulfilled, penalty clauses in case of undue unilateral early termination of the contract are to be included (Council of the European Union, 2023a).

In order to maintain the incentives for generation facilities that can provide flexibility to the electricity system to bid at their opportunity costs, technologies that typically provide flexibility to the power system, such as biomass plants, are excluded from the CfD scheme.

As one would expect, the EU requires the competitive bidding process to be open, clear, transparent, and non-discriminatory.

3.3 CFD DESIGN CHOICES

Design choices for electricity CfDs encompass several key considerations, including:
- *Technology Eligibility*: Definition of technology eligibility. This could include non-fossil generators, such as wind, solar, biomass, hydro, nuclear etc.
- *Technology-Specificity*: Technological neutral vs. technology specific CfDs.
- *Geographic-Specificity*: Geographic neutrality vs. using the CfD as an incentive for specific geographic areas. If specific sites are considered, it needs to be determined, if the sites should be matured by government/TSO or by the off-taker of the CfD.
- *Separating revenue from Generation*: Like feed-in-tariffs, depending on how the renumeration is designed, CfD may mute price signal in the day-ahead market and distort incentives to cost reflective bidding in intraday and balancing markets. By basing revenues on predicted generation generators would have stronger incentives to adapt generation to market signal. This point will be elaborated in a forthcoming section.
- *Strike Price*: Set the strike price at which the energy generated will be purchased. This can be a fixed price or one that changes over time (indexed to inflation, market rates, etc.). Government may also choose to partially expose generators to wholesale prices by introducing a revenue 'cap and floor'6.
- *Auction or negotiation Process*: The strike price of a CfD is usually set in an auction. While there are many different auction designs to choose from, the strike price is usually set in a merit order auction as a pay-as-clear price. An in-depth discussion on different auction types is provided by (Blanco et al., 2022).

[6] UK research briefing on CfDs, sep 2023. https://researchbriefings.files.parliament.uk/documents/CBP-9871/CBP-9871.pdf

- *Administrative Strike-price*: having an open auction for setting the strike price vs. setting an upper limit.
- *Contract Structure*: Setup of the structure of the contract, including its duration, terms, and the parties involved (government, energy producer, etc.).
- *Contract Length*: Contract Duration: This refers to the decision regarding the term of the contract. While long-term contracts (typically ranging from 15 to 25 years) offer greater stability for off-takers, they also commit the government for an extended period. Thus, the choice of contract length involves balancing the need for stability with the desire for flexibility.
- *Government Budget and Support*: Establishment of the level of government support and budget allocated for CfDs. This could involve considerations about the impact on taxpayers and the overall energy market. In a recent Danish CfD based tender for offshore wind power, certain caps (in billion Euro) were imposed on the accumulative payments from the government to the off-taker of the CfD and vice versa from the off-taker to the government. Such caps provide some certainty to the Treasury about future payments/revenues and at the same time partially exposes the generators to wholesale prices.
- *Non-cost Factors*: Some offshore tenders, for example in the Netherlands, have shifted focus from price to non-price criteria such as the project's impact on birds and marine habitats, knowledge sharing, research and innovation, and how well the wind farm will fit into the Dutch energy system. The wind industry supports the introduction of qualitative criteria as an alternative to selecting the lower price offer[7]. The EU's emphasis on resilience might amplify attention towards non-cost criteria, such as incentivizing the use of technologies manufactured within the EU or those with a minimal carbon footprint. On the downside, adding non-cost factors to tenders, could make the bidding process less transparent, and bring higher costs to consumers.
- *Flexibility and Adjustments*: Inclusion of provisions for adjustments or flexibility in case of changes in circumstances such as technology advancements, market conditions, or regulatory changes.
- *Inflation*: It needs also be addressed if pricing should be fully or partially regulated in accordance with inflation.
- *Contractual Obligations*: Clearly define the obligations and responsibilities of both parties, including penalties for non-compliance or project delays.
- *Risk Allocation*: Determine how risks associated with project development, construction, operation, and market fluctuations will be allocated between the government and the energy producer.
- *Review Mechanisms*: Implement review mechanisms to periodically assess the performance and effectiveness of the CfD scheme. This could involve adjustments based on lessons learned or changes in the energy landscape.
- *Transparency and Reporting*: Ensure transparency in the selection process, pricing mechanisms, and reporting requirements to maintain trust and accountability.
- *Delivery Incentives*: If penalties are set too low, there is a danger that projects might not materialise, transforming tenders into mere competitions for the right to build without actual implementation. Additionally, the financial strength and stability of bidders are crucial factors to consider. Penalties were a significant concern in the Danish tender for Anholt offshore wind, deterring several potential bidders and resulting in reduced competition.

---

[7] Offshore wind tenders sideline price criteria, led by the Dutch | S&P Global Market Intelligence (spglobal.com) , S&P Global, 1 June 2022

- *Funding Considerations*: What is the ideal source for financing CfDs? Should it be government-funded or consumer-supported? Moreover, when a CfD contract generates either a deficit or surplus, how can these financial imbalances be managed without disrupting market price signals when collecting from consumers or redistributing back into the system?

The decision for or against specific design choices is justified by the objectives. In the Swedish context, there are three design choices which seem most relevant and are discussed further:

- Geographic-specificity
- Technology-specificity
- Designing CfDs to ensure cost reflective market behaviour
- Risk sharing.

3.3.1 Geographic-specificity

Given Sweden's four electricity pricing zones, diverse energy resources, and varying population density, Contracts for Differences (CfDs) could be customized to each bidding zone to encourage development in specific regions or structured across bidding zones to ensure the most cost-effective bids across technologies.

Geographically-specific CfDs could provide incentives tailored to the unique characteristics of each zone. ENTSO-E suggest in their response to the EU Electricity Market reform proposal that locational signals or constraints in CfD auction can facilitate the development of generation assets in line with the system requirements.[8] For example, areas with a high potential for renewable energy or a low population density could receive increased CfD benefits to stimulate investment in renewable energy sources. System security could be improved for example, by CfD tenders for nuclear capacity targeting specific geographic areas.

CfDs could serve as a valuable tool for allocation of designated sites that have been predeveloped by either the Transmission System Operator (TSO) or the Government, ensuring the presence of essential elements such as environmental permits and established grid infrastructure. This approach streamlines the development process, potentially enhancing economic efficiency. Without this predevelopment, each bidding company would need to independently conduct surveys on soil conditions, perform bird counts, and execute other necessary environmental assessments. However, focusing tenders solely on these specific sites might result in the oversight of potentially more favorable locations. This approach could also restrict the range of available technologies and solutions, limiting the scope to those compatible with the designated geographic footprint. Adjusting CfDs based on geographic factors could help address regional disparities. CfD tenders for new capacity could be limited to zones with limited access to renewable resources or a high population density, such as those in the South. The use of CfDs for site allocation could potentially result in extra income for government. However, there are concerns regarding the feasibility of achieving competitive outcomes if a limited number of stakeholders are in possession of the most attractive sides. A solution would be if sites are owned by the government.

[8] https://eepublicdownloads.blob.core.windows.net/public-cdn-container/clean-documents/Publications/Position papers and reports/2023/230213_EC Public Consultation EMDR_Final submitted.pdf

Geographic non-specific CfDs could be used to ensure the most cost-effective bids of different technologies across various bidding zones. To compare bids in different bidding zones, the government would need to project power prices in the relevant bidding zones. By comparing the bid prices with the expected remuneration, the most cost-effective bids can be determined. The remuneration would depend on the capture prices of the technologies. If the Government has a solid understanding of future power prices on an hourly basis in the different price zones, it should be possible to determine which technologies would require the lowest subsidy per MWh, and thus, identify the most cost-effective bids across technologies and regions. Designing a CfD that is structured across bidding zones to ensure the most cost-effective bids across technologies could be a challenging task for the administration.

A concern raised by industrial stakeholders is how a possible change of bidding zones would change future reference prices and what commercial investment risks are associated with this. This would need to be specified in the CfD contract. In other contracts in the market, there are usually no electricity area references even when the contract is labelled as an electricity area contract. Instead, the reference point is often an individual node, such as Stockholm.

The development of offshore energy projects faces additional risks, especially when the projects are connected to more than one market in an offshore bidding zone. Here, CfDs can reduce the price risk and include a compensation in case where the agreed upon interconnector capacity has not been made available. However, dispatch still needs to align with the principles of non-discrimination and no double compensation for the same risk should take place (Council of the European Union, 2023a).

3.3.2 Technology-specificity

The extent of technological neutrality may vary, depending on how the CfD scheme is designed and implemented within a particular energy market.

The EU Commission's proposal emphasises limiting two-way CfDs and other direct support schemes to low carbon, non-fossil fuel technologies with stable operational costs that do not provide flexibility to the electricity system. Technologies in early market stages should be excluded. This restriction aims to safeguard the economic viability of high marginal cost generation technologies and maintain incentives for flexible technologies to participate in the electricity market based on their opportunity costs. However, emerging technologies might be better incentivized through other support schemes. The proposal allows possible exemptions for small-scale installations and demonstration projects while considering the unique aspects of renewable energy communities in accordance with specific directives (European Commission, 2023).

The following generation technologies are included in the proposal: wind energy; solar energy; geothermal energy; hydropower without reservoir; and nuclear energy. During the Council negotiations, the German government consistently opposed the incorporation of nuclear power into the reform, citing persisting technical and environmental challenges associated with the technology (Wehrmann, 2023).

It could be argued that CfDs should selectively be used for electricity generation methods that depend on public support for their implementation, rather than being applied universally across all aspects of power generation. Electricity generation based on commercially viable technologies can secure financing through the financial market or via power purchase agreements (PPAs). Thus, CfDs are mainly relevant to technologies offering substantive advantages to the power system but lack profitability in the market, exemplified by nuclear and offshore wind power. Newbery (2023) argues that governmental technology support can be justified not just by the price risks the technologies face, but also because the deployment drives down costs. Since different technologies have different learning rates, different levels of support are justified.

The design of a CfD allows for technological neutrality, enabling its application across various non-fossil energy sources without favouring any specific technology. Technology-neutrality avoids market distortions that may arise from favouring one technology over another. It allows the market to determine the most suitable and competitive solutions based on performance, cost, and other factors. Technology-neutral CfDs focus on the delivery of desired outcomes, such as reduced carbon emissions or affordable electricity, rather than supporting particular technologies. This can lead to more cost-effective solutions for meeting fossil-free energy targets.

Alternatively, a CfD can be tailored to support and incentivize the development of specific non-fossil technologies, providing targeted assistance and fostering growth in that particular sector. Technology specificity creates fair competition on an equal playing field within one type of technology. For emerging or less mature technologies, a technology specific CfD provides assurance and signals strong support from the government or market, fostering investor confidence. This can attract investments needed for research, development, and commercial-scale deployment. This design choice might be made if a particular technology requires special support or the least-cost competition between different technologies is not the core focus.

Technology neutral schemes could create intentional or unintentional bias towards one technology. One of the main issues are the operational costs in technology in a technology neutral auction, for example between renewable sources and nuclear. While solar and wind have close to zero marginal cost, nuclear generators have low marginal cost. A financial CfD would have to factor in that the marginal costs are asset dependent. A suitable profile could be a baseload profile. It addresses the issue with an interest in operating the facility correctly, investing in something that suits the requirement. However, plant owners might receive a less effective hedge if the approach is technology neutral.

The choice between technology specific or technology-neutral CfDs depends on the context, maturity of technologies, and the broader goals of the fossil free energy strategy. While technology specific CfDs offer the advantage of an accelerated alignment with specific policy objectives, and the opportunity to booster specific technologies, they bring the risk of potentially limiting innovation in other technologies or locking into a specific technology that might become outdated.

3.3.3 Designing CfDs to ensure cost reflective market behaviour

A key discussion point in the design of CfD schemes concerns how to develop a support scheme that incentivizes CfD off-takers to a) operate their plants according to price signals in the market and b) give them incentives to design and site plants in a way that optimise their revenues in power markets rather than just maximising the output of the plants (for example by opting for wind turbines with high full-load hours (low specific power, W/m2) or solar power plants facing west or east to increase generation in morning or afternoon hours).

The conventional CfD

The commonly known form of CfDs, also referred to in the literature as the 'conventional CfD' (Schlecht et al., 2022, 2023), is linked to the hourly generation of a specific asset.
For the electricity generator, the revenue structure that results from the conventional CfD is as follows:

$$R = p \cdot q + (f - p) \cdot q = f \cdot q$$

In this formula, R represents the revenue obtained by the generator. The variable q denotes the quantity of electricity supplied (hourly generation of a specific asset), p signifies the hourly day-ahead market price, and f represents the strike price set in an auction for the generated electricity. For the conventional CfD, it appears the formula simplifies to $R = f \cdot q$, for each time step. Effectively the conventional CfD is comparable to a fixed FiT, where the generator receives a fixed prices for the power it produces.

As mentioned in the EU proposal, it is also possible to set a minimum strike price and a maximum strike price. The generator then receives the minimum price for the supplied quantity as a minimum guarantee, plus the market price per supplied quantity up to the maximum price as a varying revenue. Only the revenue received above the maximum price needs to be paid back to the government.

A comprehensive discussion of the dispatch and investment distortions that CfDs may cause are described by Schlecht et al. (2023). In particular, the authors stipulate three issues with the conventional two-way CfDs: i) muted electricity price signals, ii) distortion of short-term intraday and balancing markets, and iii) unhedged volume risks.

Muted price signals in day-ahead markets

In the way conventional CfDs are designed, the generator revenues across all hours of production equal the strike price and thus, market prices lose significance in influencing the decision-making process of the generator. Power plants are incentivized to generate independently of how prices in the day-ahead market develop. Fundamental economics dictate that power plants should have incentive to produce only when power prices are above their short run marginal costs, but under a 'conventional CfD', they would have incentive to bid at negative prices in the spot market.

Consequently, they fail to incentivize increased production during scarcity, reduced production during periods of low prices, scheduling maintenance when demand is lower, or investing in generation assets that could yield higher-than-average market prices.

In certain situations, this could cause the 'true' merit order curve to be mixed up, as for example a nuclear generator under a CfD, despite of its fuel costs, would have incentive to bid at a negative price in the day-ahead market, thus potentially squeezing out solar power or wind power plants, not under a CfD scheme, that would bid a price of zero or close to zero. Depending on the market situation, in some hours this bidding behaviour will result in negative prices in the spot market, increasing the need for government subsidies under the CfD beyond what is justified by economics. If a large portion of the generation fleet is under 'conventional' CfDs the effects on day-ahead price formation could become substantial.

Distortion of intraday and balancing markets

'Conventional CfD' leads to inefficient bidding behaviour in intraday and balancing markets. Schlecht et al. (2023) provides the following example: If the strike price stands at 80 €/MWh and the day-ahead price reaches 200 €/MWh, a wind power generator would face a cost of 120 €/MWh for each unit of electricity produced in that hour. If the intraday or imbalance price falls to under 120 €/MWh, it becomes a rational decision for the generator to curtail their output[9]. The opposite effect takes place during periods of low electricity prices, leading generators under 'Conventional CfDs' to bid below their variable costs in intraday market.

Unhedged volume risk

While CfDs efficiently mitigate price risks, they do not hedge against volume risks. Generators remain fully exposed to volume fluctuations, like the variability in wind availability throughout the year. As Schlecht et al. (2023) point out, not only do volume risks remain unhedged, but CfDs also eliminate a natural hedge present in power markets: the inverse relationship between prices and wind availability when selling electricity to spot markets, which typically mitigates volume risk. Normally, a year with low wind might result in reduced volumes but is compensated for by higher prices. However, within a CfD framework, a year with low wind leads to notably reduced revenues as the lower volume no longer benefits from above-average prices, intensifying the financial impact.

Alternatives to the 'Conventional CfD': Longer reference period

Considering the abovementioned challenges with the conventional CfD, a number of proposals have been made (and tried out) to tweak the conventional CfD to provide fewer market distortion. One of the solutions has been to extend the so-called *reference period.* If the reference market price is calculated on an hourly basis, the Contract for Difference (CfD) essentially functions as a fixed price agreement. However, if the reference market price spans a yearly or monthly duration, the developer will either receive or pay the disparity between the strike price and this reference price, which may not mirror the actual hourly market rate (resulting in annual or monthly adjustments to the CfD premium). Consequently, longer reference periods create incentives for short-term market integration by maintaining short-term market price signals (Blanco et al., 2022). However, as pointed out by Schlecht (2023), since CfD payments depend on actual generation, and CfD payment may be forecasted by

[9] Explained in another way: if the price in the intraday markets drop to for example 119 €/MWh the plant owner would earn 81 €/MWh in that market (200 €/MWh-119 €/MWh = 81 €/MWh), which is one 1 €/MWh more than the strike price it is guaranteed by producing in the spot market.

generators with reasonable accuracy, bidding behaviour will also be affected in the case of long refence periods.

Alternatives to the 'Conventional CfD': Separating revenue from generation

Another, potentially more attractive solution to avoid the distortion of short-term prices, is to separate the CfD revenue from actual generation or dispatch decisions, as suggested by ENTSO-E in their response to the public consultation process of the EU's Electricity Market Design[10]. In some cases these contracts are called 'deemed CfDs' whereas the terminologies 'asset independent', 'Capability-Based CfD (CB-CfD)* and 'financial CfD' are used in other contexts. An overview of alternative designs to the conventional CfD are depicted in Figure 3-2. The agreed-on compromise of the Electricity Market reform proposal between Council and the European Parliament from December 2023 mentions specifically that design options could include injection-based CfDs with one or several strike prices, a floor price, or capability or yardstick contracts for differences[11].

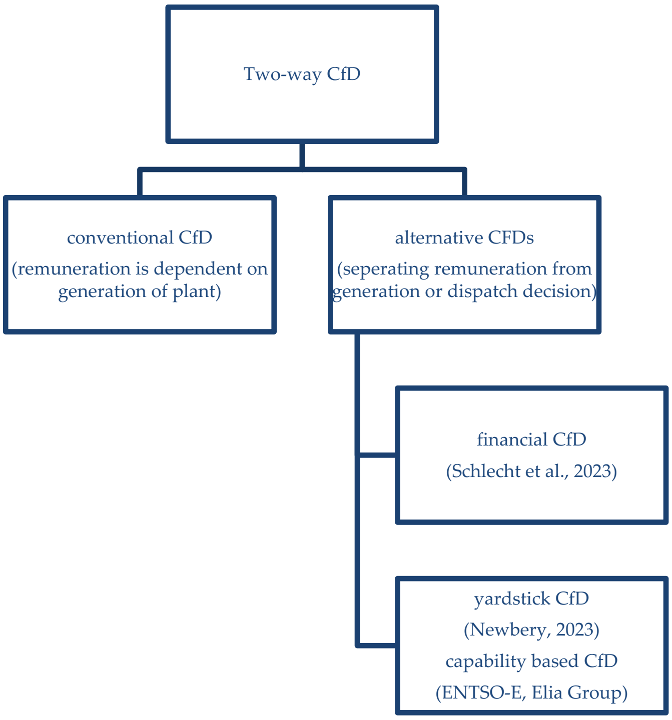


Figure 3-2 Overview of CfD types according to asset specificity

Yardstick CfD

Newbery (2023) suggests a 'yardstick CfD', for which the CfDs payments are decoupled from a specific asset's generation and based on site-specific generation forecasts. The Yardstick CfD is based on an hourly contracted volume that aligns proportionally with the local renewable output per megawatt (MW). Schlecht et al.

[10] https://eepublicdownloads.blob.core.windows.net/public-cdn-container/clean-documents/Publications/Position papers and reports/2023/230213_EC Public Consultation EMDR_Final submitted.pdf

[11] https://data.consilium.europa.eu/doc/document/ST-16964-2023-INIT/en/pdf

(2023) criticize however that the yardstick CfD only addresses price risks, while solar and wind generators still face weather-related volume risks.

Capability based CfD

The capability-based CfD (CB-CfD) measures the volume by the generation potential of an asset. Payments are determined based on capability forecasts rather than the real transmitted electricity. The state compensates the CB-CfD income, calculated as the disparity between the market income and the strike price multiplied by the anticipated injection (capability). The reference quantity q is then defined as the capable volume (MWh) of the generation asset. By decoupling remuneration from actual injection, CB-CfDs hedge the volume risk for generators and reduce the risks for market distortions. Decoupling remuneration from the actual injected quantity becomes even more relevant for offshore generators in hybrid projects, as the different bidding zones dispatch decisions influence the injection quantity. ENTSO-E[12], as well as national TSOs such as Elia Group advocate for employing the asset's capability, representing its maximum anticipated injection, as a more precise metric than actual injection. The advantage of CB-CfDs is that the CfD payment is based on expected, not actual performance, thus electricity market prices still guide the decision-making.

While CB-CfDs reduce potential intraday and balancing distortions, Schlecht et al. (2023) criticize that the CB-CfD still rely on an individual asset's generation potential and that there is a potential for data manipulation.

Moreover, Schlecht et al. (2023) point out that both yardstick CfDs and Capability-based CfDs reduce the incentives to increase the value of electricity through technology and siting choices.

Financial CfD

Schlecht et al. (2022, 2023) introduced the term 'financial CfD' as another form of asset independent CfD. In this model, the government ensures a fixed hourly payment to the generation asset, which is determined competitively in a procurement auction. This payment does not change during the lifetime of the contract. The generation asset reciprocates by remitting spot market revenues to the government, not the revenues of its own asset, but the revenues of a reference plant (or a group of reference plants), a baseload profile or the demand profile. This strategy aims to alleviate risks by separating payments from the tangible production of the asset, where the government provides a consistent monthly payment, and the generator reimburses the government with the spot market revenue based on the reference volume multiplied by the strike price, offset by the market-generated income.

The reference plant's revenues could for example be based on aggregated production of solar or wind on country level or in a specific bidding zone. For nuclear power a baseload profile could be used, where all hours are weighted equally.

The asset independent CfDs offers two key advantages: Firstly, plant owners are incentivized to optimize plant design and operation efficiency and thus it prevents

[12] https://eepublicdownloads.blob.core.windows.net/public-cdn-container/clean-documents/Publications/Position papers and reports/2023/230213_EC Public Consultation EMDR_Final submitted.pdf

distortion in operational decisions, ensuring unbiased market responses. Generators and consumers maintain their reactivity to short-term scarcity in the power market, remaining exposed to spot price incentives, thereby promoting market efficiency and responsiveness. It is Ea's assessment that incentives to provide ancillary services would also be unaffected under a financial CfD. Secondly, it removes the aforementioned volume risk, because the fixed hourly payment is independent of actual plant.

Schlecht et al asserts that the financial CfD also removes distortions in investment and repowering decisions because all payments are asset independent. In our (Ea's) opinion, this may not entirely be the case. As Schlecht and others have discussed, the government should require collateral to back up the financial Contracts for Differences (CfDs). This is particularly crucial if the CfD is viewed as a subsidy rather than a risk mitigation measure. In the former case, the CfD could potentially be priced at strike prices significantly higher than the expected future power prices. This would make it attractive for market players to enter financial CfDs without investing in physi-cal fossil free generation assets.

In such situations, it is imperative that the government ensures that the contracts are backed by physical assets. These assets, under normal weather and operational conditions, should be capable of delivering the amount of electricity specified under the CfD.

Schlecht et al. (2023) caution that regulators should be careful in defining these collateral requirements. They argue that these requirements could incentivize plant design and specification to maximise the variables which the collateral requirements ask for. If the contract is profitable for investors and collateral requirements only regard nominal capacity, ignoring site-specific wind availability and potential full-load hours, this could incentivize turbine designs that maximise nominal capacity at the expense of other factors. Thus, there is a risk that financial CfD may distort investment decisions.

Most likely, the financial CfD would also need to be accompanied by continuous documentation, either yearly or monthly. This documentation would demonstrate that the physical assets backing the financial CfD contracts are operational and capable of producing the specified amount of power. This measure would ensure transparency and accountability in the implementation of CfDs.

Therefore, while it is clear that financial CfDs can prevent distortions in operational decisions, it is less evident that distortions to investment decisions can be fully removed.

As mentioned, the financial CfD could be based on a baseload profile, a demand profile or profile matching the specific assets that the government would like to promote. If the government seeks a technology neutral competition a baseload profile or a demand profile are preferable since these profiles match the needs of the electricity system.

The downside of applying a base load profile or a demand profile is that they increase the financial risks for variable renewable energy generators and the associated risk premium is likely to be factored into the bidding prices. If a demand profile is applied, it would be important to accurately define what types of demand is considered, since the system demand profile may change considerably as direct and indirect (PtX) electrification picks up.

In a technology-neutral tender, companies are expected to invest in a combination of technologies, such as wind and solar power, to create a cumulative generation profile that closely aligns with the baseload profile.

If the government aims to encourage particular technologies, it may be beneficial to customize the profiles forming the Contract for Difference (CfD) to align with these specific technologies. This approach helps minimize risk premiums, ensuring a more economic outcome.

The CfD based on a baseload profile is probably the simplest financial CfD setup. It involves four cost/revenue streams:

- **Government Remuneration**: The plant owner receives a fixed remuneration from the government each hour. This fixed amount is the central aspect of the tender process, and the company willing to accept the lowest remuneration wins the tender. Importantly, this remuneration is not tied to the actual electricity generation or market prices.
- **Capital and Operation Expenditures**: The plant owner is responsible for covering the capital and operational expenses of the plant. For wind and solar energy plants, most costs remain constant regardless of actual generation. In the case of nuclear facilities, some costs (such as fuel) may be influenced by the level of generation.
- **Payment to Government**: The plant owner pays the government hourly profits based on a base load generation profile. These benchmark profits are calculated by multiplying the day-ahead spot price for each hour by size of the contract. Consequently, the payment is directly proportional to the average electricity market price but is independent of the actual generation by the plant.
- **Power Sale in the Electricity Market**: The plant owner sells the generated power in the electricity market and earns revenue from this sale. The plant owner can optimize revenue by strategically choosing markets that offer the highest returns relative to risk. This can include day-ahead markets, bilateral contracts, long-term Power Purchase Agreements (PPA), intraday markets, ancillary services markets, or a combination of these options. By optimising the output, for example through technology and location choice, the plant owners can increase their profit.

CfDs designed specifically for wind or solar power would resemble this setup, with the exception of the payment to the government, which would align with the profits of an artificial solar or wind power facility.

Financial CfDs could also be an effective instrument for nuclear energy. However, while the operating costs of solar and wind are close to zero, the operating costs for nuclear generation put a risk that the costs will not be covered, if the reference price is (for an extended period of time) between zero and the OPEX. Therefore, in the case of nuclear, the CfD could be designed to take this into account, see example below:

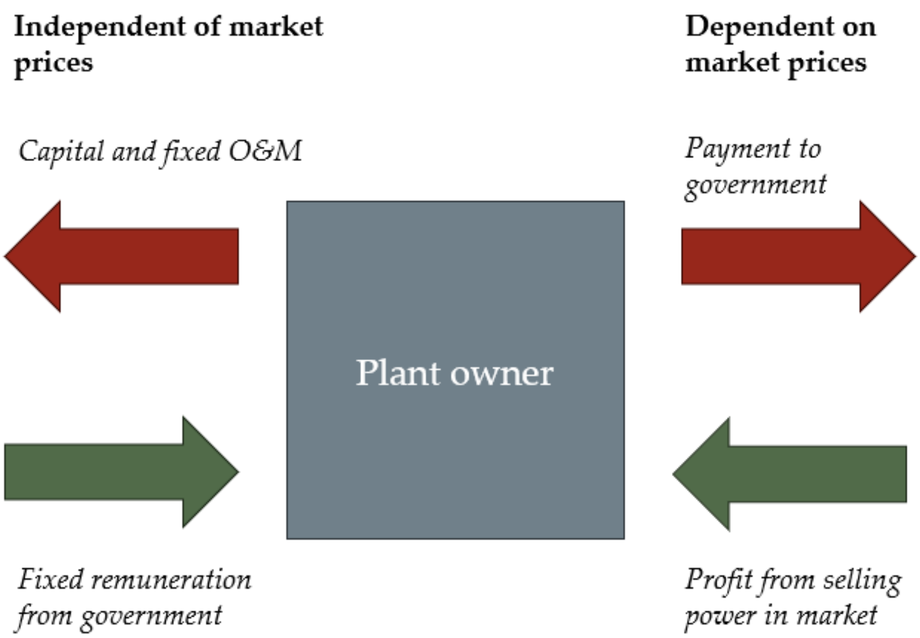


Figure 3-3 Cost (red) and profit (green) streams of a power plant under financial CfD.

Example: Financial CfD for a nuclear power plant
A financial CfD is made for each 1 MW of nuclear power over 40 years. The contract is based on a baseload profile and the short-run operational costs of the refence nuclear plant is assessed to be 10 EUR/MWh.

In a competitive bid with other companies a renumeration of EUR 80 per hour is obtained. This results in a fixed annual income to the plant owner of EUR 700.800 (8760 hours * 80 EUR/MWh) per MW. This is paid out during the lifetime of the contract. According to Schlecht et al (2003), payments are made on an hourly basis, but since the payments are independent of the plant's actual production, payments could also take place one a monthly or annual basis.

Each hour, if the spot market price is above the plant's short run marginal cost of estimated 10 EUR/MWh, the plant owner should pay the difference between the spot market price and the 10 EUR/MWh to the government. In hours, where the market spot market price is below 10 EUR/MWh, the plant owner does not pay the government anything. Therefore, if in a given hour, the power price is for example 100 EUR/MWh, the plant owner would have to pay the government 90 EUR/MWh (100 EUR/MWh-10 MWh).

The plant owner sells the generated electricity in the spot market and receives a revenue from this. Thus, the incentives to a) invest in a flexible power plant and b) to adjust generation according to market prices are maintained Flexible design and operation may lead the plant owner to make more profit in the market than what the plant owner has to pay the government.

From the perspective of the plant owner, it may be a reasonable assumption that the payments to the government and profits from selling power in the market more or less balance out. Therefore, the renumeration should be able to cover the fixed cost of the plant, i.e. capital costs and fixed operation and maintenance costs. In this way, the financial CfD ensures, that plants with the lowest cost are preferred while at the same providing incentives for efficient design and operation.

Technology-neutral financial CfDs

The Tidö agreement advocates for technology neutrality, with a focus on creating a level playing field among fossil-free technologies. Achieving technology neutrality in financial Contracts for Differences (CfDs) could be simplified by using baseload profiles as the foundation for the contracts, instead of the previously mentioned reference wind or solar plants.

Such technology neutral CfDs offer several advantages. They foster competition across different technologies, align well with existing forwards and futures, and are simpler to define. However, applying baseload contracts to solar and wind profiles could introduce additional risks for investors. This is because they would need to bear the risk associated with the potential deviation of capture prices for solar and wind generators from baseload prices.

3.3.4 Risk sharing[13]

The investment in non-fossil fuel power plants is faced by a number of risks. While project-specific risks like reliance on specific suppliers for critical components fall under the business responsibility of the project developer, renewable energy developers also face policy and market design risks, which are difficult to hedge (Newbery, 2023). CfDs mainly address the risk of market price volatility, which is a systematic risk that effects the whole sector and is thus relevant to both the investor and the state. Market price volatility is influenced by overall economic conditions, energy market dynamics, electricity supply and demand, and changing weather patterns. This volatility poses a threat to future power generation income, raising uncertainties about whether the substantial upfront capital costs for plant construction and installation can be sufficiently covered. Particularly, solar and wind generation, with their low marginal costs, may contribute to reduced electricity prices. CfDs address this risk by shifting the burden of market price volatility from the project developer/generator to the government entity through a minimum revenue guarantee (Blanco et al., 2022).

While discussions often highlight consumer protection against elevated prices as a benefit of CfDs, consumers would bear the financial burden when market prices fall below the stipulated strike price. This scenario places the risk of "low prices" squarely on consumers, which could be particularly sensitive in instances where CfDs feature relatively high strike prices. On the government's side, CfDs introduce uncertainty about the annual costs of CfD support schemes. In comparison to an upfront investment support, the budget needed for the duration of the CfD remains uncertain as it depends on the future power prices levels. This situation raises the question of how to fairly allocate risk between the project developer and the government entity.

[13] While there are numerous risks associated with the investment in non-fossil fuel power plants, we here focus on market price volatility as a systematic risk that the project developer cannot mitigate by diversification. Several other risks are discussed by Blanco et al. (2022).

Two strike prices

One option to share the risks is by introducing two strike prices, as depicted in Figure 3-4. Depending on how the range is set, the risk is shared between plant owner and government. Setting a wider range, limits government payments and exposes the plant owner to varying prices, while giving a plannable limit. The lower the lower strike price, the lower the risk hedge on the side of the plant owner. The higher the upper strike price, the lower the pay-back payments for the plant owner.

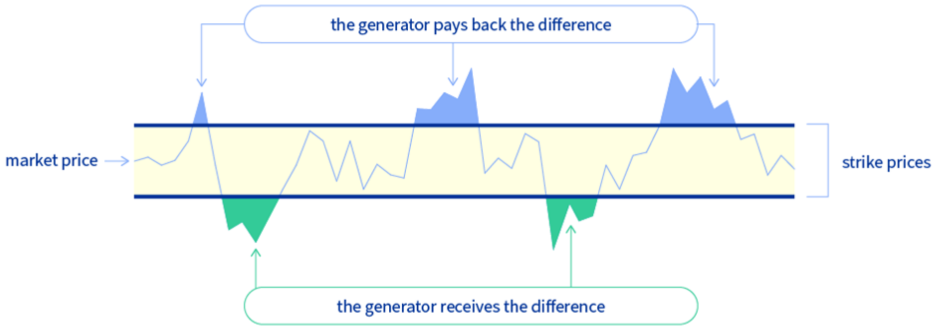


Figure 3-4 Two-way Contract for Difference.
Source: Council of the European Union (2023)

Payment cap

Another way to share the risk is by implementing a payment cap to limit the level of payments. An example for this was the concept of the Thor CfD in Denmark, for which a cap on payments from both the government entity as well as the project developer was set. The cap on the government side was set to DKK 6.5 billion (SEK 9.91 billion) and the cap for the project developers ('Concession Owner Cap') was set to DKK 2.8 billion (SEK 4.27 billion). These caps were established at a level not anticipated to be reached, considering the current electricity price forecasts of the Danish Energy Agency (DEA) (Danish Energy Agency, 2020). The values of the caps were based on real prices (i.e. 2018 prices) and the subsidy payments would therefore be adjusted for inflation every year to their 2018 value. It is important to note that these caps are net caps, meaning that the project developers' payments to the state were subtracted from the accumulated subsidy paid by the government. Figure 3-5 provides an example of the payments. While providing a fixed cap allows both the plant owner and the government treasury to plan their budgets, the challenges of setting the caps appropriately are evident in the Thor CfD. Five out of six bidders proposed a zero CfD price, leading to the resolution of the auction through a drawing of lots. The bidders believed that even with the payment of the Concession Owner Cap in the initial phase, they would still achieve profitability over the contracted CfD lifetime by selling power in the electricity market.

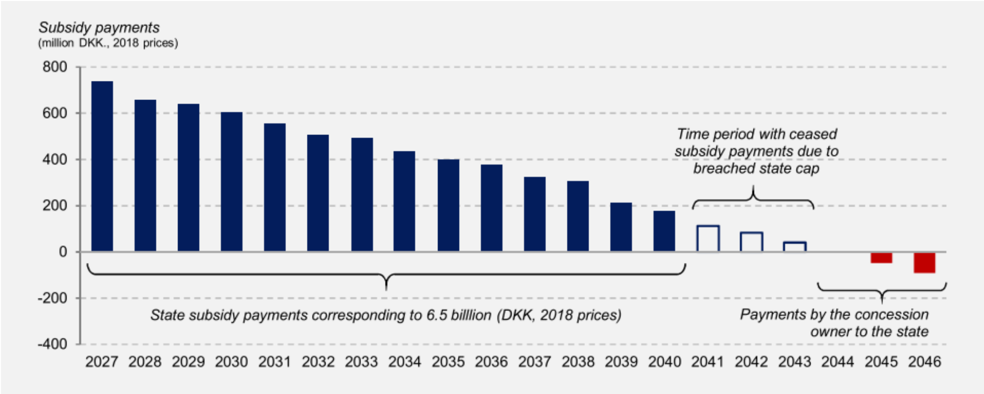


Figure 3-5 Thor CfD example of a possible subsidy payment profile and the application of the government side payment cap.

Source: Danish Energy Agency (2020)

3.3.5 Winner's curse

Contrary to simpler auction models, insights from auction theory indicate that resulting CfD auctions might not achieve the most efficient allocation. Bidders could still be incentivized to strategically bid, potentially encountering the "winner's curse." This phenomenon refers to the regret felt by successful bidders who believe that their win indicates an "overbid," whether in terms of price or quantity. Essentially, winning the auction might be viewed as "bad news" by bidders, suggesting they may have bid naively. Depending on the fine structures underlying the specific CfD tender, there is a risk that projects struck by the "winner's curse" will never be realised be developers. The recent offshore bidding system in Germany attempted to mitigate this by using an open bidding process across multiple stages, resembling a Dutch auction style.

3.3.6 CfDs vs PPAs

The European Commission's proposal highlights the complementary roles of two-way contracts for difference and power purchase agreements (PPAs) in advancing the energy transition and making renewable and low carbon energy accessible to consumers. Member States are encouraged to have the flexibility to choose the instruments for achieving their decarbonization goals. PPAs involve private investors contributing to increased deployment of renewable and low carbon energy while ensuring long-term, stable electricity prices. Similarly, two-way contracts for difference enable public entities to attain the same objective on behalf of consumers. Both instruments are deemed crucial in meeting the Union's decarbonization targets by promoting the deployment of renewable and low carbon energy, ultimately delivering low-cost electricity generation benefits to consumers (European Commission, 2023). Considering equal strike prices. CfDs would be the preferred option by project developers over PPAs, because of the more reliable counterpart (government). PPAs would need to offer a significant economic benefit. CfDs thus might cause volume distortions in the PPA market.

3.3.7 Central matchmaking

Central matchmaking in the context of Contract for Difference (CfD) refers to a mechanism or system that facilitates the pairing of electricity generators with buyers or off-takers. In a CfD arrangement, the central matchmaking process aims to efficiently connect renewable energy project developers (generators) with entities interested in purchasing the generated electricity at a predetermined price.

Breakdown of the central matchmaking process:

Generator Identification: The system identifies renewable energy project developers who are seeking investment and have the capacity to generate electricity, typically from renewable sources like wind, solar, or other low-carbon technologies.

Off-taker Matching: The central matchmaking system then matches these generators with potential off-takers, which can include utilities, corporations, or other entities interested in purchasing renewable electricity. These off-takers commit to buying the generated electricity at a specified price over a predetermined period.

Price Determination: The agreed-upon price is often set through a competitive bidding process or other transparent mechanisms.

Risk Mitigation: The CfD, including the central matchmaking process, plays a crucial role in mitigating risks for both generators and off-takers. Generators receive a guaranteed price for their electricity, providing financial stability, while off-takers secure a fixed supply at a known price, protecting them from market price volatility.

Government Involvement: In many cases, governments or regulatory bodies oversee or facilitate this central matchmaking process as part of their efforts to promote fossil free energy.

We have not assessed whether a model for central matchmaking is relevant or suitable for the Nordic electricity market setup.

3.3.8 EU approval of UK CfD for Hinkley point C

In 2014, the European Union approved the UK's CfD's scheme for the Hinkley Point C nuclear power station. This decision upheld the UK's authority to determine its energy mix but required compliance with EU state aid rules to ensure fair competition within the Single Market. The approval allowed the UK to provide financial support, including a long-term operating contract and substantial incentives, to EDF for the construction of Hinkley Point C. Despite concerns about potential market distortions due to the large subsidies and the extended contract period, the approval marked a significant step in the UK's pursuit of nuclear energy.

3.3.9 CfDs and Capacity Mechanisms

There is a growing interest in introducing capacity mechanisms in Sweden. Svenska Kraftnät, the Swedish TSO, has expressed concerns that the energy-only market may not be able to provide the necessary level of security of supply and suggests a market-wide capacity mechanism[14]. Occasionally, the interaction between CfDs and capacity markets is being discussed, considering potential implications for generator incentives

---

[14] https://www.svk.se/en/about-us/news/news/svenska-kraftnat-proposes-a-future-capacity-mechanism-to-ensure-resource-adequacy-in-the-electricity-market/#:~:text=Svenska%20kraftn%C3%A4t%20therefore%20assesses%20that,a%20market%2Dwide%20capacity%20mechanism.

and reliability. However, it is important to clarify the objective of each instrument: While CfDs provide security for investments in baseload, capacity mechanisms aim to incentivize peak load. CfDs add more baseload to the system, thus per se improving security of supply, however capacity contracted under CfDs might have limited flexibility and could implicitly increase the need for capacity mechanisms by reducing the operating hours for conventional power plants, thus increasing the demand for peak capacity. It is crucial to assess how capacity contracted under a CfD is considered in a capacity market to avoid paying twice for the same service. If capacity under CfDs is made eligible for the capacity market it would reduce the need for renumeration under the CfD and increase the incentives for the contracted capacity to be available in scarcity situations.

Both Contract for Difference (CfDs) and capacity markets serve a common purpose by contributing to the protection of consumers from the effects of high electricity prices. In the specific context of long-term CfD *baseload* contracts, an important dynamic becomes apparent. These contracts not only bring stability to project developers but also create incentives for them to invest in additional capacity, to ensure supply even during periods of peak demand. The motivation for project developers to expand their capacity is rooted in the contractual commitments that encourage them to consistently meet electricity demand.

References

Beiter, P., Guillet, J., Jansen, M., Wilson, E., & Kitzing, L. (2023). *The enduring role of contracts for difference in risk management and market creation for renewables*. https://doi.org/10.1038/s41560-023-01401-w

Blanco, A. A., Hoel-holt, A., Lotz, B., Riekeles, H., & Vennemo, H. (2022). *Norwegian Offshore Wind Auctions*.

Council of the European Union. (2023a). *Proposal for a Regulation of the European Parliament and of the Council amending Regulations (EU) 2019/943 and (EU) 2019/942 as well as Directives (EU) 2018/2001 and (EU) 2019/944 to improve the Union's electricity market design - Analysis of the final co* (16964/23; Issue December). https://data.consilium.europa.eu/doc/document/ST-16964-2023-INIT/en/pdf

Council of the European Union. (2023b). Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending Regulations (EU) 2019/943 and (EU) 2019/942 as well as Directives (EU) 2018/2001 and (EU) 2019/944 to improve the Union's electricity market design - General approach. *Interinstitutional File: 2023/0077(COD) 14339/23*. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=consil%3AST_14339_2023_INIT

Energimyndigheten. (2023). *Scenarier för Sveriges energisystem 2023 - med fokus på elektrifieringen 2050 (Scenarios for the Swedish energy system 2023 - with a focus on electrification by 2050)*. www.energimyndigheten.se

European Commission. (2022). Guidelines on State aid for climate, environmental protection and energy 2022. In *Official Journal of the European Union*. https://eur-lex.europa.eu/legal-content/EN/TXT/?toc=OJ%3AC%3A2022%3A080%3ATOC&uri=uriserv%3AOJ.C_.2022.080.01.0001.01.ENG

European Commission. (2023). Regulation of the European Parliament and of the Council amending Regulation (EU) 2019/943 and (EU) 2019/942 as well as Directives (EU) 2018/2001 and (EU) 2019/944 to improve the Union's electricity market design. *COM(2023) 148 Final*, *0077*. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52023PC0148

Newbery, D. (2023). *Efficient Renewable Electricity Support : Designing an Incentive-compatible Support Scheme*. *44*(3), 1–22.

Schlecht, I., Hirth, L., & Maurer, C. (2022). Financial Wind CfDs. *ZBW – Leibniz Information Centre for Economics*, 17.

Schlecht, I., Maurer, C., & Hirth, L. (2023). Financial Contracts for Differences. *ZBW - Leibniz Information Centre for Economics*. http://hdl.handle.net/10419/268370

CONTRACTS FOR DIFFERENCE (CFD) IN THE SWEDISH ELECTRICITY MARKET

In March 2023, the European Union (EU) proposed a reform of the electricity market design. This reform includes rules for support of non-fossil fuel power generation based on two-way Contracts for Differences (CfDs). The EU market design proposal allows some flexibility to each member state in terms of the design of the CfDs, provided that CfDs are designed to maintain incentives for power generation facilities to operate efficiently and participate actively in the electricity markets. This report maps and discuss the design choices involved. EA Analyse has in its mapping of CfDs discussed the different design choices such as strike price, technology neutrality and location specifications. This report provides overall guidance on how a technological neutral CfD tender could be designed.

A new step in energy research

The research company Energiforsk initiates, coordinates, and conducts energy research and analyses, as well as communicates knowledge in favor of a robust and sustainable energy system. We are a politically neutral limited company that reinvests our profit in more research. Our owners are industry organisations Swedenergy and the Swedish Gas Association, the Swedish TSO Svenska kraftnät, and the gas and energy company Nordion Energi.

Energiforsk