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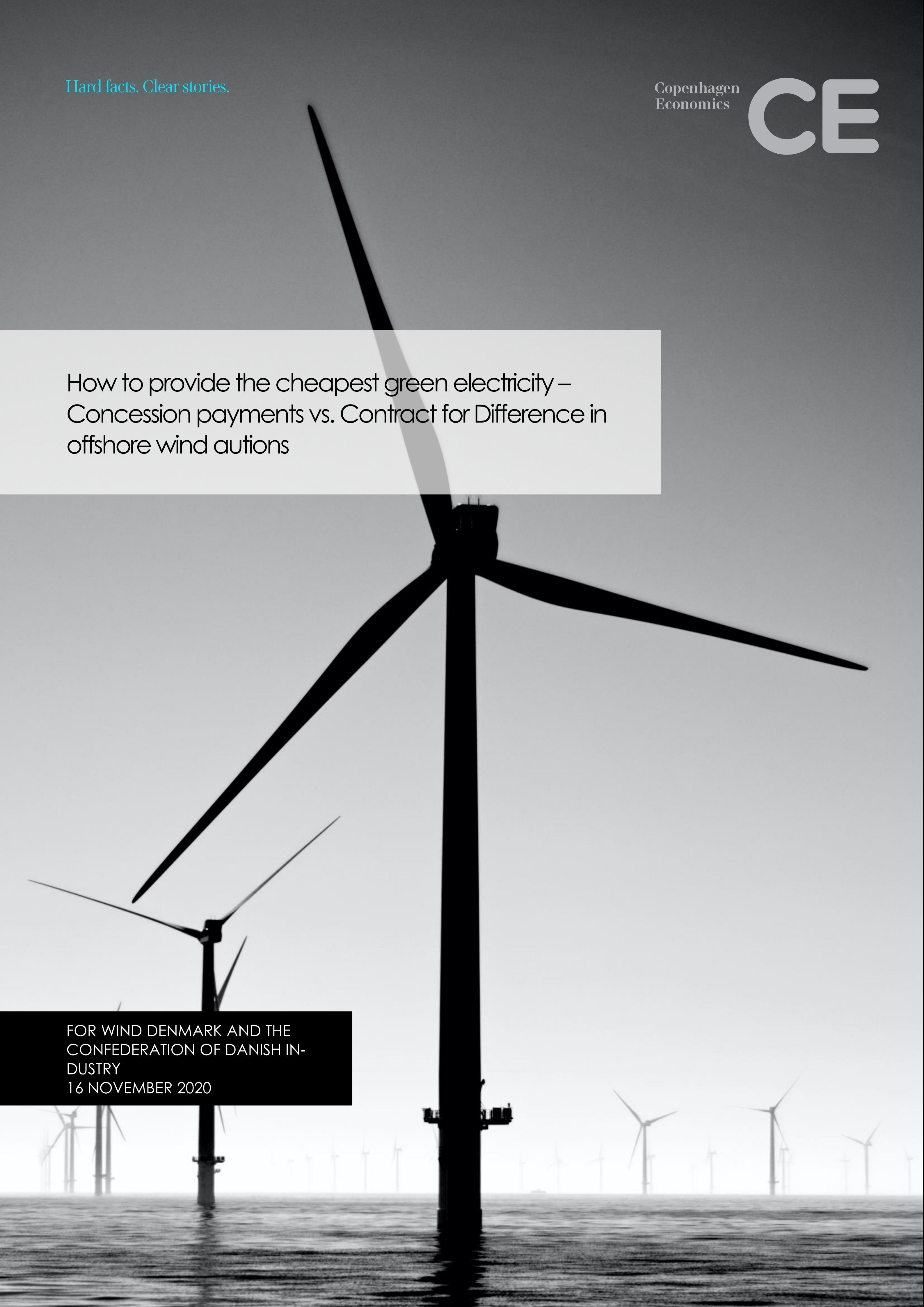

How to provide the cheapest green electricity – Concession payments vs. Contract for Difference in offshore wind autions

FOR WIND DENMARK AND THE CONFEDERATION OF DANISH INDUSTRY
16 NOVEMBER 2020

Copenhagen Economics

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EXECUTIVE SUMMARY

Recent years have seen large decreases in the cost of offshore wind, which have resulted in reduced subsidies and even offshore farms being built without subsidies or with 'negative subsidies. This has led several countries to consider future auction designs for offshore wind. Various proposals have been raised with no agreement on an "optimal auction design".

In Denmark, the upcoming tender of the Thor Offshore Wind Farm in 2021 will apply a "Contract for Difference" (CfD)-based auction design, whereas the model for the 2022 tender of the Hesselø Offshore Wind Farm has not yet been decided. Nor have the tenders for the two 'energy islands' or hubs for hybrid projects combining offshore wind farms with interconnectors planed in the Danish North Sea and Baltic sea, with 3 and 2 GW connected capacity respectively. In the Danish Energy Agreement of June 2018 (Energiaftale 2018), it was agreed that an offshore wind analysis should, among other things, assess models for creating government revenues from offshore wind. Using Denmark as the case in point, this analysis compares CfD-based auction designs with a design based on concession payments, e.g. where the winner is the developer who is willing to pay the highest price to the state for permission to develop and operate the farm.

From a socio-economic perspective, the optimal model should focus on how to provide the lowest possible electricity price for consumers – both private consumers and industrial consumers – and how to avoid production of green electricity becoming a new tax base.

In this analysis we show how an auction design can help assure this by building on the cornerstone of the long-proven model for efficient competition through CfD auctions, that have been used for more than a decade in different variations in different countries.

The main conclusion is that auctions with competition based on the highest concession payments will only serve to raise electricity prices and damage business competitiveness in general, and competitiveness of the offshore wind resource relative to other electricity producing technologies in particular. Continued efficient competition through CfD's should therefore be the cornerstone of an optimal auction design.

The study has four sub-conclusions:

1. The cost of renewables – offshore wind in particular in Denmark– will determine the long-term average power prices, and thus auction design should ensure the lowest possible cost (LCOE) for offshore wind
2. An increase in the cost of offshore wind through auction designs based on concession payments would increase power prices and thus weaken the competitiveness of businesses in countries using this model
3. Low cost renewables and thus competitive power prices can best be assured through efficient competition via CfD auctions
4. Using a hybrid-CfD model with a reference price based on the country-wide wind-weighted average wholesale electricity price will be optimal for offshore wind CfD's, as it simultaneously minimizes the cost of offshore wind (LCOE) and incentivizes design and operation choices maximizing the value instead of the volume of produced energy.

1.
This analysis does *not* evaluate whether or not the development in LCOE of offshore wind, the future electricity price level, the availability and terms of finance etc. makes it viable to expect the offshore wind deployment predominantly to be merchant or subsidy free[1] and thus providing the basic prerequisite for applying concession payments. Assuming a scenario were such a future is going to materialize this analysis answers the question of how to design adequate auctioning scheme.

1 INTRODUCTION AND KEY TAKE AWAYS: OPTIMAL AUCTION DESIGN FOR LOW ELECTRICITY PRICES

The transition to green energy, and specifically the transition to greener production of electricity, should have the consumers' interest at the very core. This will imply a constant focus on delivering green electricity at the lowest possible price for the consumers and thus society as a whole.

Low prices for energy and electricity will not only benefit private consumers (households) but also the business community, because they are dependent on competitive electricity prices in their production.

This is crucial for current industrial energy intense power consumers as well as everyday households.

If governments lose focus on the interests of consumers and try instead to draw government revenue from offshore wind auctions, this could lead to rising electricity prices. If the Danish government decides to use auctions based on concession payments, they should be aware that they risk undermining Denmark's aim of becoming a home for competitive hydrogen and power-to-X production, as this will be highly sensitive to power prices.

This raises the question: how do we ensure the lowest possible and most competitive prices for electricity? To answer this question, we must look at what determines the price of electricity.

1.1 Offshore wind will significantly determine electricity prices in the future

In the deregulated north west Europe electricity market, the price of electricity is determined by the marginal electricity production for each hour.

Today, the price of electricity is primarily determined by the marginal production costs at thermal power plants, i.e. coal and gas plants. In general, the price is determined by a mix of power production prices from coal and gas fuel costs and the carbon price. This is because the marginal electricity production in the north west Europe region is generally thermal production from either coal or gas, depending on the level of demand in any given hour.

However, during some hours there is a lot of renewable energy in the grid, and the price of renewable electricity production will significantly affect the average price. Since the marginal cost of producing electricity from renewable energy is zero, allowing for more electricity from renewables in

[1] Cf. Considerations on the viability of the business case of future merchant offshore projects in the Netherlands. See e.g. "*The business case and supporting interventions for Dutch offshore wind – a report to the ministry of economic affairs and climate policy*", AFRY, March 2020.

the grid will drive down electricity prices, and the more expensive producers will eventually be pushed out of the market.

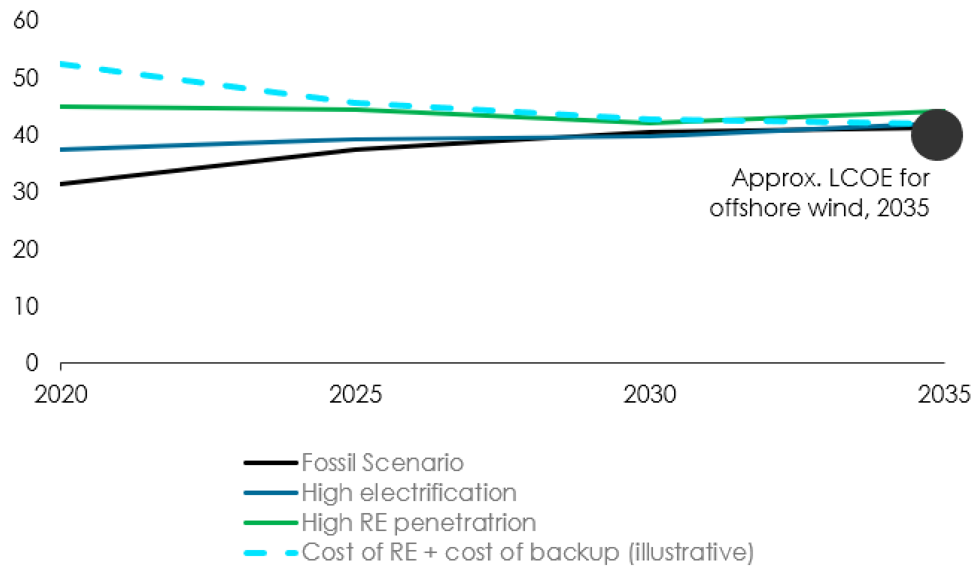
The current dominance of thermal fossil fuel power plants in determining the electricity price will likely change in the future. An analysis by Dansk Energi[2] shows that around 2030, the average price of electricity will instead be determined by the production cost of renewables. More specifically, in Denmark it is assumed it will be determined by the Levelised Cost of Energy (LCOE) for offshore wind, including backup and/or integration cost[3] (see Figure 1 and Dansk Energi, Elpris Outlook 2019). As the figure shows, the prices in all three analysed scenarios tend to converge toward a price determined by the LCOE for marginal renewable energy. The LCOE of renewables, and in particular offshore wind, will determine the average annual electricity price.[4] The reason is that, given an efficient market design, developers will continue to invest in additional renewable energy up to the point where the electricity price ensures that the captured price for renewable energy equals the LCOE for renewable energy. The renewable energy, including backup, will put a cap on power prices in the long run. The reason is that in a system with "energy-only power markets", which can drive new investments, the power price must converge to a sustainable level for investors to cover the LCOE. The analysis estimates that this level will be around 50-55 EUR/MWh in Denmark by 2030. The analysis also shows that this level is set by the costs of new renewable energy plus backup. This implies that the costs (LCOE) of investments in new renewable energy will have a crucial effect on the future power price, reducing the importance of carbon and fossil fuel prices.

[2] Dansk Energi (2019), Elpris Outlook 2019. Dansk Energi - Danish Energy - is a non-commercial lobby organization managed and financed by its member companies, mainly the distribution system operator (DSO)

[3] Reflected in the expected downlift in capture prices of renewable energy

[4] It is important to underline that when stating that offshore wind will be setting the electricity price in the future, we are not saying that offshore wind (with the close to zero marginal cost) will be the price setting technology in the hourly price formation. It is the *long-term average* electricity price that will be set by the *LCOE* of offshore wind

Figure 1
Three power price scenarios in western Denmark (DK1)
EUR/MWh



Note: The average price will be somewhat higher than the LCOE for offshore wind due to the fact that wind will generally capture prices somewhat lower than the average price, as prices are lower when there is much wind in the system.

Source: Illustration by Copenhagen Economics based on Dansk Energi (2019), Elpris Outlook 2019. LCOE for offshore wind 2035 based on Danish Energi Agency (2020), "Teknologikatalog for produktion af el og fjernvarme". LCOE for offshore wind 2036 calculated with a WACC of 4 % (See 4.1, Table 1).

Since the LCOE for offshore wind will largely determine the price of electricity in the future, it is important to ensure *i)* the lowest possible LCOE for offshore wind, and *ii)* that the best and cheapest offshore resources are utilised.

1.2 The auction design for offshore wind can secure consumers a low price of electricity

Both private and industrial consumers will benefit from low electricity prices, and this will eventually benefit production and growth. As described in the previous section, offshore wind will likely determine the long-term average price of electricity in Denmark in the future. Politically, Denmark should therefore focus on creating an auction design for offshore wind that will ensure the lowest possible cost of offshore wind, and thus the lowest possible electricity price for consumers.

However, in the Danish energy agreement from 2018 it was agreed that an analysis of offshore wind should, among other things, assess models for creating government revenues. *S*etting up a model with “”resource rent on offshore wind is in direct conflict with ensuring the lowest possible electricity price for the consumers, as such taxation would increase prices.

Traditionally, Denmark has had healthy competition in the market for offshore wind through Contract-for-Difference (CfD) auctions[5]. These have served to push down prices for offshore wind, as it is effectively the developers who can deliver the lowest total LCOE for the project that have been given the concessions. This has led developers to continuously drive down LCOE. In light of the positive experiences with CfD's, future auctions should also be based on the same auction design.

In addition to carrying over the healthy competition from CfD-auctions into the future auction design, five elements of the model will be crucial for ensuring cheap offshore wind:

1. *A*void taxing the production of green electricity through concession payments for offshore wind.
2. In light of 'zero-bid'-auctions, governments should maintain healthy cost reducing competition based on lowest price. The alternatives are to either use qualitative criteria (also known as 'beauty contests') or concessions payments, both of which will lead to more expensive offshore wind. In order to ensure healthy competition, it is necessary to apply a CfD-version with no 'opt out' possibility within the contract period. The reason for this is, that with an "opt out" possibility, investors could effectively bid with a CfD bid price low enough to ensure winning the concessions and opting out at day 1. This would again leave evaluation of the bids to rest on qualitative criteria.
3. CfD's can ensure reduced investment risk, reduced required rate of return and reduced cost of capital (WACC) for offshore wind and thus ensure the lowest LCOE, which will eventually result in the lowest possible power prices. This de-risking can be achieved without crowding out wholesale electricity market price signals for the offshore wind farm operator by applying a 'hybrid CfD' with a wind-weighted reference price, thereby incentivizing the turbine owner to maximize the value of the kWhs produced and not just the volume of kWhs. The risk should therefore be partly borne by the state, while in return the state benefits from revenue sharing of a two-sided CfD, opening up the possibility of 'net negative subsidy' contracts.
4. Protect developers of offshore wind against 'electricity price risk'. This is based on the argument that, in the long run, the price of electricity is largely politically determined,[6] while giving turbine owners an incentive to maximize the value of the kWhs produced and not just the volume of kWhs. The risk should therefore be carried by the state.
5. Optimize the utilisation of the best and cheapest offshore wind resources by allowing for 'overplanting'. 'Overplanting' is a situation where the winner of the auction can install as much capacity as is economically optimal within the available area, while the available grid capacity in the connection point is fixed, leaving the power plant larger than the grid capacity.

In the following chapters we will go through each of these elements and establish how a new auction design can accommodate them.

[5] Previous Danish auction designs for offshore wind have been one-sided, meaning that subsidies could not be negative, should the power price be higher than the CfD strike price. This has been changed in the auction design for Thor, where payments can go either way (from the developer to the state or from the state to the developer).

[6] See also chapter 3.

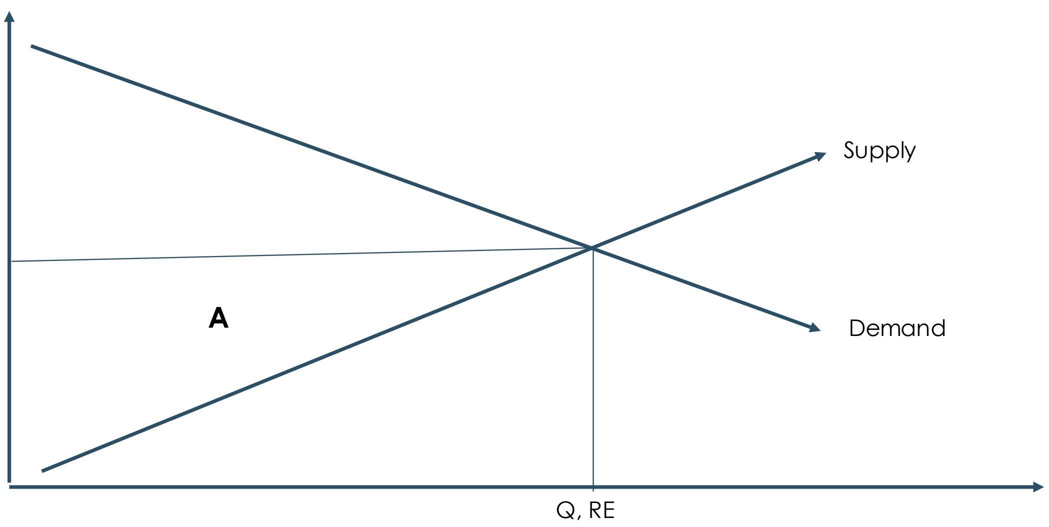
2 AVOID TAXATION THROUGH CONCESSION PAYMENTS

Offshore wind is an almost inexhaustible resource compared to the expected energy consumption in Northern Europe, and as offshore wind is the most abundant renewable energy source in Denmark, taking the limitations on suitable locations for onshore wind into account, it is expected that offshore wind will be the marginal and price-setting technology that will determine the price of electricity in Denmark. This is also in line with the power prices as presented in Dansk Energi Elpris Outlook 2019.

Another important element in keeping the price of electricity as low as possible is avoiding concession payments. An auction design that can generate concession payments implicitly shows that *i)* the price of electricity is unnaturally and unnecessarily high and higher than the marginal LCOE, because if this was not true the producers would not be able to pay a 'tax' on the offshore wind resource, and *ii)* the state holds back offshore wind resources, because if they did not the market would build enough offshore wind to drive prices down to the LCOE, and thus the willingness to pay a concession payment for access to build on a specific area would disappear.

Concession payments will serve as a tax on the green production of electricity. The only situation in which this should not be the case is if the supply curve for offshore wind was significantly increasing. Should the supply curve be significantly increasing, you could argue that there would be room for a congestion payment paid by the cheapest producers, see Figure 2, where A represents a potential congestion payment from the cheapest offshore projects. Such congestion payments would not increase power prices.

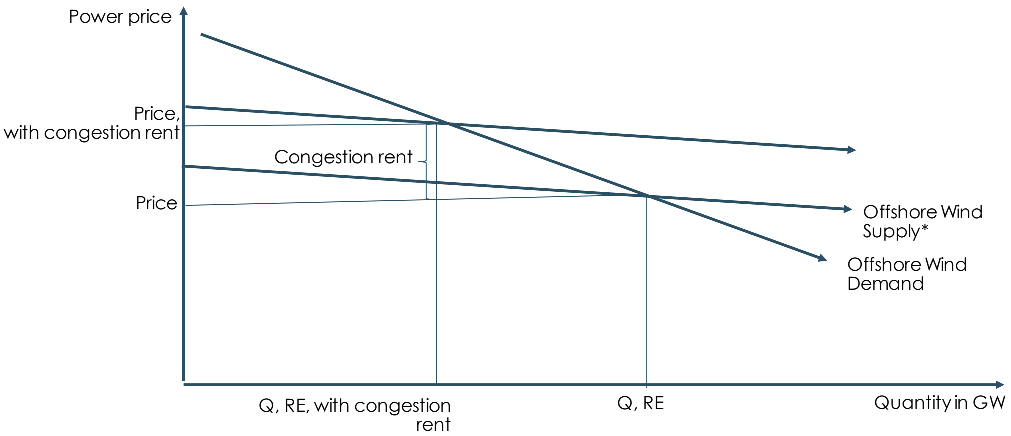
Figure 2
Congestion payment for rent in a market with increasing supply costs



Source: Copenhagen Economics illustration

However, if the supply curve flattens or even diminishes, a congestion payment would increase LCOE for *the marginal project and thus power prices on the margin*, see Figure 3. This shows that a congestion rent *will* increase power prices.

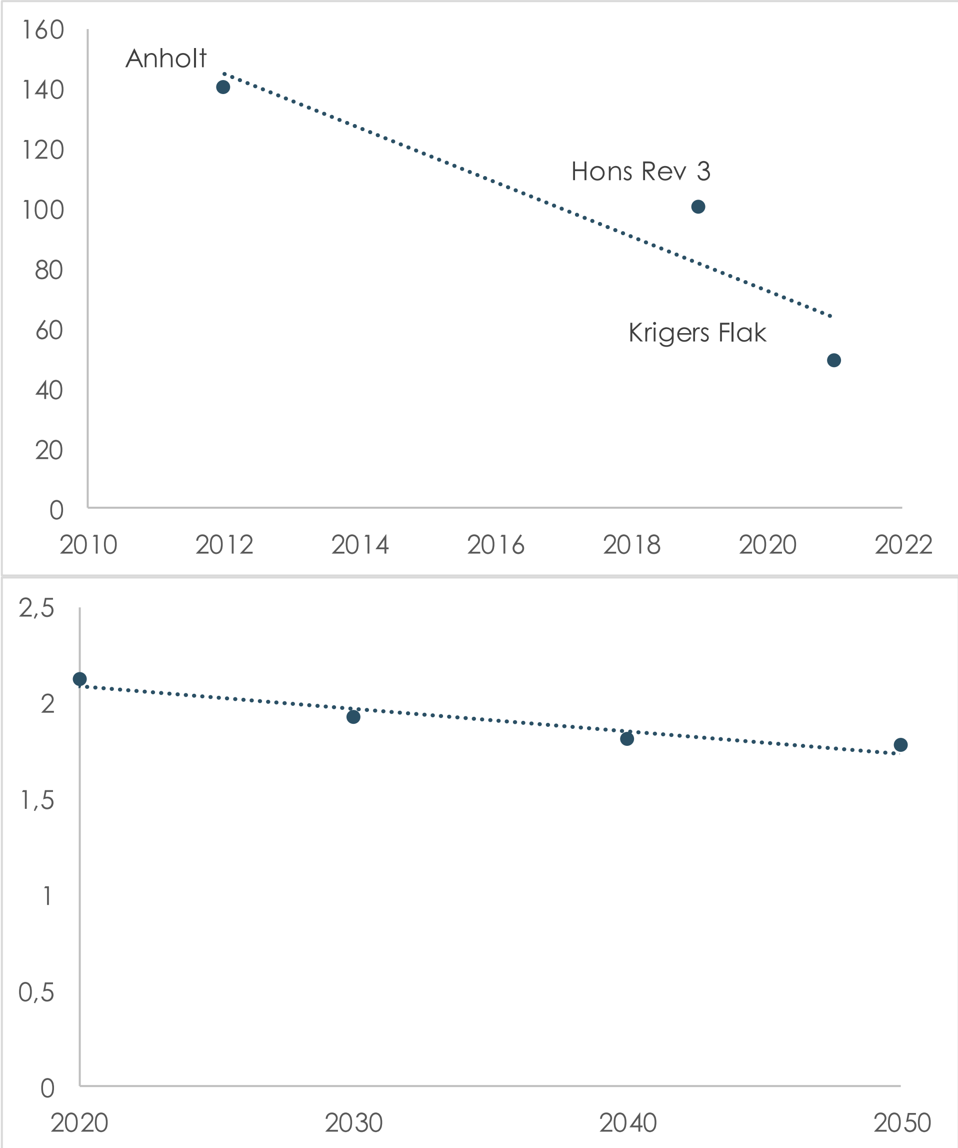
Figure 3
Congestion payment for rent in a market with a flat or diminishing supply curve



Source: Copenhagen Economics illustration
Note: * Offshore wind supply is expected to see decreasing marginal costs over time, as for each new project, historical and future projections will be less costly than the one before, in a margin where capacity is incrementally building up over time, with each new project receiving its own bid price (under the current auction design).

As illustrated in figure 3, a flat or diminishing supply curve will leave no room for congestion payments for collection of rents without increasing power prices. And there are strong arguments for believing that the marginal project in the coming decades will continue to be cheaper than the previous projects, see Figure 4, and thus we will see an increasingly flat or negative supply curve. In this scenario, congestion rents will lead to increasing LCOE and power prices.

Figure 4
Historical winning CfD bids (top panel) and investment costs trend in mEUR/MW (bottom panel) in Denmark
CfD bid in EUR/MWh on the top pane, million EUR/MW (installation cost) on the bottom pane



Source: Top Pane: Danish Energy Agency, CfD bids received with one time opt out option and a contract period of 50,000 full load hours, corresponding to approx. 10-12 years, and no subsidy in hours with negative wholesale electricity prices. Commissioning year on x-axis in top pane. Bottom pane: Danish Energy Agency, "Teknologi Katalog 2020". Year of final investment decision on x-axis in bottom pane.

It is also a result of basic economic theory, that production taxes will distort prices and consumer behaviour, leading to a 'deadweight loss' in welfare.[7] The deadweight loss stems from the fact that

[7] A socio-economic deadweight loss refers to a situation where regulation, market design or structures results in a sub-optimal production level with inefficient high prices.

production taxes will increase the market price as they increase production costs. This means that *without* the taxes, there are producers who are willing to increase supply at a price that is lower than what consumers are willing to pay. With taxes this supply is supressed, though the market itself would benefit from an increased supply. Any supply at a cost lower than the level consumers are willing to pay constitutes a welfare gain, as consumers can get their demand satisfied and gain from trade as long as the price is lower than this level. Though the deadweight loss can be argued to be small for households, there can be significant deadweight losses for industry, which would also lead to outsourcing of domestic industry production and loss of domestic jobs, as industry is in international competition and several industries are highly responsive to power prices.

It is therefore socially desirable to avoid such a tax and increase the social welfare by reducing the deadweight loss. In general, economic theory deems production taxes – and in this example concession payments – as an unsuitable instrument for creating revenue for the state.

In addition, the higher cost of offshore wind caused by concession payments will result in a lower supply of renewable energy in Denmark. This can lead to an increase in the import of electricity, which may increase the share of fossil fuel electricity, leading to higher CO_2 emissions.

It is important to remember here that if the market for offshore wind is not restricted by the State through non-environmental restrictions on access to the seabed, then the expected net subsidy for offshore wind will be 0, as exactly enough offshore wind will be built to match the power price.

2.1 Concession payments increase the price of electricity, decreasing the competitiveness of Danish industry

Higher prices caused by concession payments will lead to socio-economics costs, as they will distort the power market and increase power prices for all consumers. Copenhagen Economics has estimated how much the LCOE, and hence the price of electricity, will increase based on different levels of concession payments. The results show that every time the concession payment increases by 1 million DKK/MW, the price of offshore wind and thus electricity will increase by 14 DKK/MWh, see Figure 5.

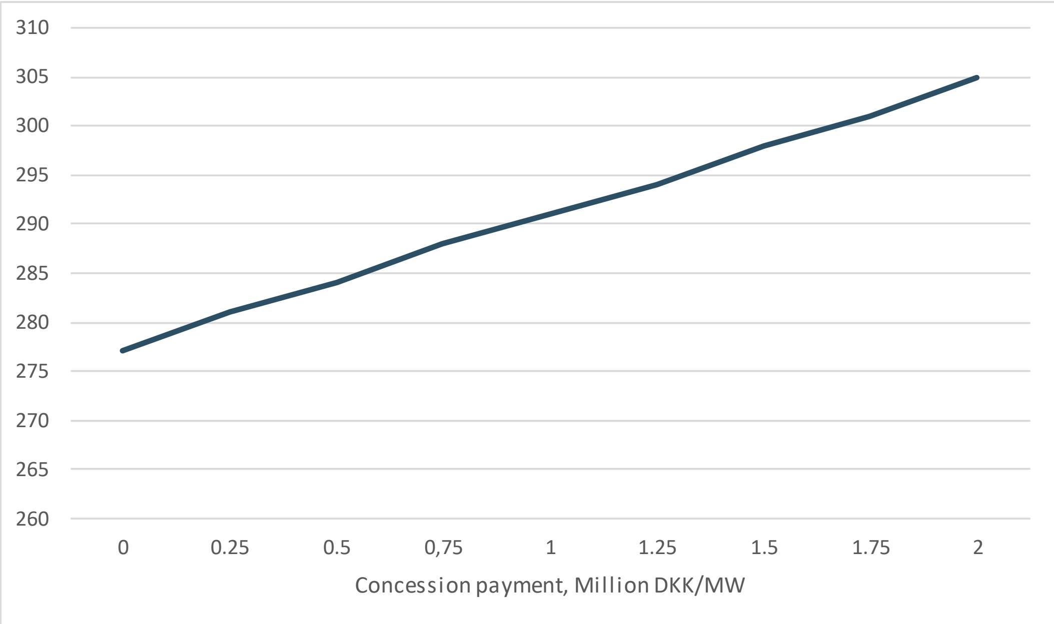
Concession payments can generally take two forms. *Either* the state sets a fixed payment per installed MW or the like in a given tender, *or* a concession auction is held. The concession payment will be part of the auction design, such that the winner will (fully or partially) be chosen based on who will pay the highest concession payment. Though both options are inefficient, due to the arguments stated above, the latter option will serve to drive up concession payments, leading to the bizarre result that the auction design will de facto maximize the socio-economic loss (See also Figure 3).

Increasing electricity prices will decrease the competitiveness of Danish industry because Danish companies will have to pay relatively more for electricity than their competitors. This can be shown by an example: a concession payment of 1 million DKK/MW will increase the price of electricity by 291 - 277 = 14 DKK/MWh by 2030 (1.9 EUR/MWh), see Figure 5. According to the Danish Energy Agency's projections[8], the Danish electricity use, including new datacentres and PtX, will use approx. 58 - 71 million TWh by 2030. With a concession payment of 1 million DKK/MW will therefore

8 Danish Energy Agency (2020), "Analyseforudsætninger til Energinet"

increase their electricity costs by approx. 812 – 994 million DKK per year (109 – 133 million EUR). The higher average electricity prices will also affect Danish companies, and especially hurt the competitiveness for electricity intense industries in global competition. This will also reduce the attractiveness of Denmark as location for large datacentres.

Figure 5
Concession payments increase the price of electricity
DKK/MWh



Source: Copenhagen Economics based on its own calculations and Danish Energy Agency, Teknologikatalog. Calculations based on 6% WACC.

3 GOVERNMENTS SHOULD MAINTAIN HEALTHY COST REDUCING COMPETITION BASED ON LOWEST PRICE

There have been several examples of zero-bids in offshore wind tenders over the last few years in different EU countries. This raises the question of how to "pick the winning bid". One option is to allow for negative fixed price premiums. These will effectively serve as concession payments, which have been shown to be inefficient above. Another option is to include "qualitative measures". Such auction designs have been tried, e.g. in the Netherlands, but have shown several difficulties. It is outside the scope of this report to go further into this, but further insights can be found in Lassen et al. (2020), "Dutch tender challenges conventional thinking of offshore wind" and Ministry of economic affairs and climate policy (2020), "The business case and supporting interventions for Dutch offshore wind".
We therefore recommend carrying over CfD's in the new auction design, due to the following arguments:

- *Firstly*, CfD tenders reduce the risk for developers and thus the LCOE for offshore projects, which will lead to lower power prices as argued above

- *Secondly*, CfD tenders ensure healthy competition for the lowest LCOE. Concession payments as an alternative award criterion will result in unhealthy competition, where concession payments are pressed upwards – and there is thus a competition to drive up the LCOE and power prices, to the disadvantage of the green transition and consumers
- *Finally*, an award criterion based on "zero bids" and qualitative criteria will not only increase risk and thus the LCOE compared to CfD's, but also increase LCOE due to the additional qualitative elements on the projects, giving rise to additional costs that would not occur in a competition for lowest price

4 THE POWER PRICE RISK SHOULD BE ALLOCATED ACCORDING TO CONTROL OVER RISK

The price of electricity is volatile, and investments in renewable energy based on the spot power price are risky. The volatility means that the producer is never sure what price to expect. The fluctuations in price and associated risk are called the electricity price risk. In this section, we will describe how this risk can be minimised and who should bear the risk.

4.1 How does electricity price risk affect offshore project economy?

The electricity price risk is important, because a low risk implies a low LCOE and hence a low price of electricity, e.g. see IEA's Offshore Wind Outlook 2019. To date, the risk and the LCOE for offshore wind investments have effectively been decreased by using auction models based on Contracts-for-Difference (CfD) in different variations across most European markets. Since 2010, the winning bid prices for Danish offshore wind farms have decreased from over 1 DKK/kWh to approx. 0.4 DKK/kWh in 2016.[9]

CfD's have effectively been used to reduce the LCOE because they reduce the power price risk for the developer and create a steadier income flow for the producer. Having a secure, stable income flow will affect the required return on capital, which is often covered by the term Weighted Average Cost of Capital (WACC). The WACC and the LCOE move together – the lower the WACC, the lower the LCOE and hence the price of electricity. The CfD therefore reduces the LCOE by reducing the income flow risk and hence the WACC. This is especially important for the green transition, because the up-front investment costs or capital expenditures (CAPEX) constitute a high share of the LCOE for wind and solar power, which means that the LCOE is highly dependent on the project WACC, see also IEA Offshore Wind Outlook 2019 and AURES ((https://auresproject.eu/)).

To effectively keep the LCOE down, the auction design must therefore make sure to keep the WACC at a low level, for example by using CfD's. ARUP (2018) shows how the WACC differs for a wind farm producer depending on whether or not they are protected from risk with CfD's. The study finds that the WACC is reduced by 1.2 to 2.7 percentage points if a CfD is used to decrease the risk, see Table 1.

[9] Danish Energy Agency, winning bid price for offshore concessions

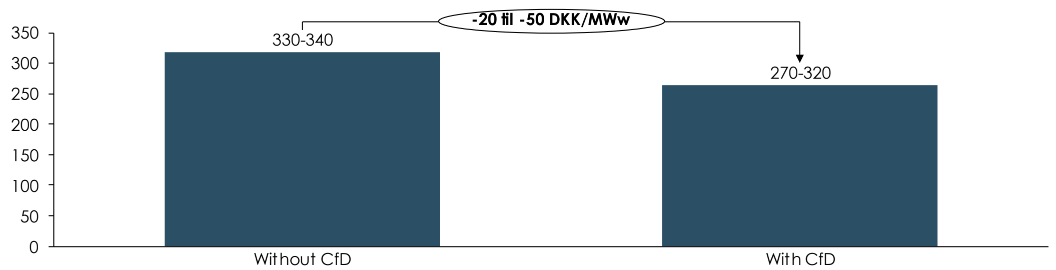
Table 1
WACC after tax

	Without CfD		With CfD		Difference	
	Low	High	Low	High	Low	High
WACC	4.6%	5.3%	1.9%	4.1%	-2.7%	-1.2%

Note: The WACC used for this calculation is based on onshore wind farms. Though there might be smaller differences in the WACC for onshore and offshore wind, the power price risk exposure effect on the WACC for onshore and offshore wind can be assumed to be comparable. WACC after tax is calculated using the capital cost after tax. This after tax WACC has been inflation adjusted using the CPI.
Source: ARUP (2018), Cost of Capital Benefits of Revenue Stabilisation via a CfD, page 10

The differences in WACC may seem small, but even small differences will affect the LCOE through risk reduction. We find that an auction design that includes a CfD will reduce the LCOE by 20 to 50 DKK/MWh compared to an auction design without a CfD, see Figure 6. The risk reduction through CfD's will only become increasingly important in future years as technology costs for offshore wind are expected to decrease[10]. We find that technology and investment costs make up 75% of the LCOE for offshore wind, and a reduction in technology costs will therefore drive down the price of offshore wind. To reduce the price even further, it is important to keep an auction design that removes the electricity price risk by using a CfD model, and not by adding an additional charge to the price through concession payments.

Figure 6
Effect of the electricity price risk on the LCOE for offshore wind, 2030
DKK/MWh



Note: The following have been used in the calculation: A real WACC of 6.4%-7.2% for the situation without a CfD and 1.9%-4.1% for the situation with a CfD. LCOE is calculated including costs of grid connection as given in the source.
Source: ARUP (2018), Cost of Capital Benefits of Revenue Stabilisation via a CfD, page 10 and Energistyrelsen, teknologikatalo, 21 – Large wind turbines, updated April 2020

4.2 Control over a number of core factors affecting the electricity price

When talking about investment projects, there is always a risk to be placed by one of the parties involved in the investment. It is economically efficient to place this risk with the party that has *i)* the

[10] See for instance Danish Energy Agency (2020), "Teknologikatalog for el og varmeproduktion"

greatest knowledge of the future development of the risk, and *ii)* the greatest control over the development of the risk.[11]

There is a widespread understanding that the producers on the market have the greatest knowledge about future developments. However, in the electricity market this is not the case because many of the developments are controlled by politicians.

The premise of this report is that the future power price in the longer run will be determined by the LCOE of the marginal renewable energy. This is true, *given the framework for energy and climate policies, including the power market design, grid development, taxes, subsidies etc.* This also means that significant changes to those factors can affect both the LCOE of marginal renewable energy, and ultimately whether the level of renewable energy is restricted to a level where it will not be the price setting technology. Thus, political decisions can effectively have a large effect on the power price in both the short and longer term.

We find that eight key factors are affected and controlled by politicians and authorities on a national and European level, namely:

Under political control and/or outside the control of the wind power developer:

- Carbon prices
    - *Through political design and interventions in the ETS market*
- Interconnection capacity
    - *Interconnector capacity and investments are to a wide degree based on political decisions and regulation*
- Political forces decommissioning coal (and other fossil fuel fired) power plants
    - *Through forced political out-phasing of coal plants etc.*
- Electrification of heat and transportation
    - *Through electricity taxation and other political incentive designs*
- Increased flexible demand
    - *Through regulatory and political incentive design for flexible demand*
- Future onshore and offshore wind capacity
    - *Through concessions and political/public acceptance of onshore wind*
- Increased number of power price bid-zones
    - *Implementing new bid-zones based on national physical grid congestion is under political control and subject to recurrent 'bidding zone reviews'*
- Capacity mechanism for thermal, flexible power
    - *The future power market design is to a wide degree political decided – or decided by government owned TSO's*

These factors are also in line with the factors identified as key drivers for power prices by the Danish TSO, Energinet, in the publication, "Hvad påvirker elprisen" (2016).

Due to the political control of the factors affecting the price of electricity, economic theoriy[12] argue that the power price risk should to a wide extent be allocated to the State and politicians, e.g. through an auction design with CfD's.

Another argument for allocating power price risk to the State is that the Danish Government itself estimates that in a scenario where the 70 % GHG reduction target is reached, power prices will be

[11] See for instance Max Abrahamson, Journal of the British Tunnelling Society, Vols 5 and 6, November 1973 and March 1974; and CIRIA Report R 79 'Tunnelling – improved contract practices' (1978)

[12] E.g. Shen-Fa and Xiao-Ping (2009), "The rule and method of risk allocation in project finance"

above the estimated LCOE for offshore wind.[13] This de facto means that the State itself believes that a CfD should be risk free for the State, given that the State is set to fulfil the 70 % reduction target.

4.3 Reference price – preferring value over volume

Another important aspect of creating the auction design is deciding which reference price to use as a comparison for the strike price in the CfD when calculating the (positive or negative) subsidy for a wind farm.

The reason to discuss the reference price is that it is crucial for developers' incentives to maximize the captured power prices, which is the same as maximizing the socio-economic value of the power prices. In earlier CfD auction designs, an hourly spot power reference price has been applied. By doing this, the developers have zero incentive to react to wholesale power market price signals, as a low captured price in one hour will be 1-to-1 countered by higher subsidies for the same hour. However, a CfD can achieve a de-risking of the power price *level* without crowding out wholesale electricity market price signals for the offshore wind farm operator. This can be done by applying a 'hybrid CfD' with a wind-weighted reference price, as argued below.

We argue that it will be most cost-efficient and result in the lowest LCOE to use a wind-weighted average power price as the reference price, where the wind-weighted price is based on the average captured prices for all Danish offshore wind farms.

Using the wind-weighted annual, average power price can be compared to two other previously used models, where one is the classic CfD model, as described below:

1. **Classic CfD – Actual hourly captured prices for the wind farm**
    a. In this auction design, the subsidy is calculated on the basis of the difference between the hourly captured spot-price for the respective wind farm and the CfD strike price. This model has the disadvantage of the wind farm developer and operator not having any incentive to increase the market value of the production (e.g. the captured power prices) as any downlift from lower captured prices will be offset by a higher subsidy
2. **Hybrid CfD – Average power price as the reference price**
    a. In this auction design, the subsidy is calculated on the basis of the difference between the average spot price and the CfD strike price over a defined period, e.g. a month or a year. Using a reference price ensures that the total revenue of the wind farm operator in the given period will depend on the market value of the captured prices in the spot market (capture price +/- the fixed premium from the CfD). This auction design thus removes the flaw from the hourly captured price design. However, the design significantly increases the risk for the developer, as they have little control over the *overall, average downlift for offshore wind*. The reason is that the average downlift largely depends on political decisions. These decisions include:
        i. *Total electricity demand, which is largely the result of policy design and energy taxes*

[13] See Danish Energy Agency (2020), "Analyseforudsætninger til Energinet" in Danish

ii. *Availability of export opportunities to other markets through interconnectors, where the interconnector capacity is a result of political decisions*
iii. *Access to power storage and flexibility of electricity demand, which again, to some degree, is the result of policy design and the power market design,* which is in turn defined by policymakers and regulators as well as *DSO's and their tariff designs*

Summing up, this auction design serves to remove the risk from the average power price level, but will still leave the developer exposed to the risk from *higher, average downlift, which is outside the developer's control.*

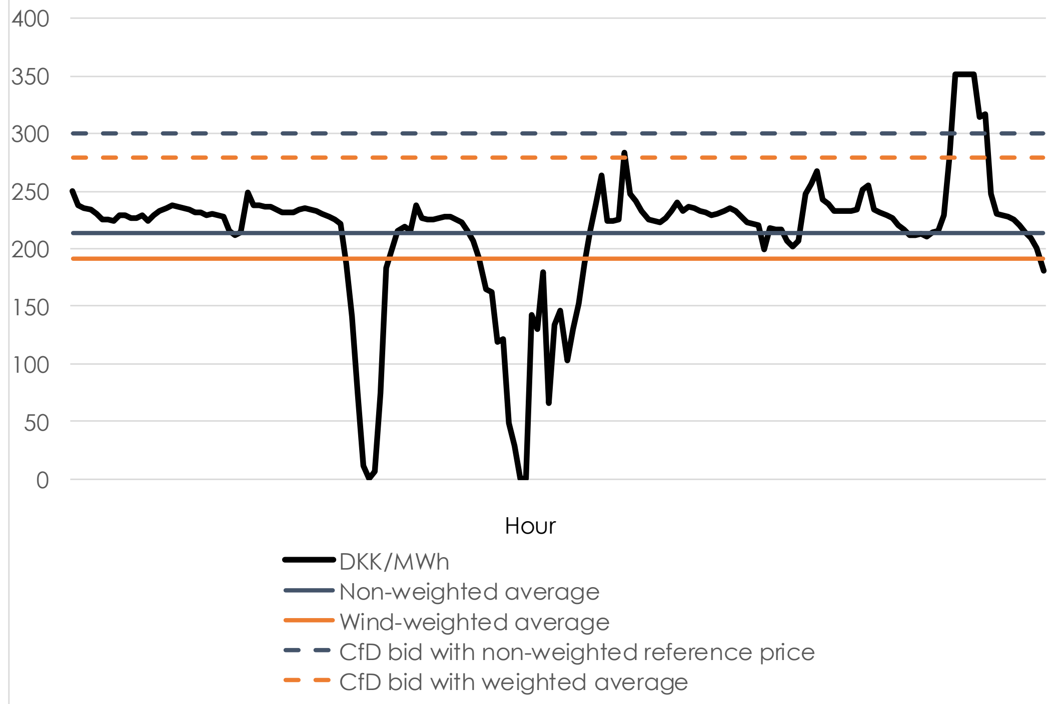
3. **Hybrid CfD – average wind-weighted annual power prices as reference price**
   a. There is an auction design option that can ensure there are incentives for optimizing the market value of the produced energy, while avoiding reintroducing the risk which the CfD auction design is meant to overcome. This can be done by using country-wide, 'wind-weighted' average electricity prices, where the wind-weighted price is an average for the entire country's wind power fleet. The reason for using the wind-weighted average annual price of electricity as the reference price in the contracts is, as stated above, that the downlift is largely the result of external decisions outside the control of the wind developer. Thus, the *risk associated with the annual, average downlift* should not be borne by the wind power developer, but rather by the decision makers who are more in control of this downlift.

Two natural concerns can arise when using the wind-weighted average, annual power price as the reference price:

- Firstly, that wind developers do not get the right incentives to capture high prices
- Secondly, that the reference price will of course be lower, which might appear to entail higher CfD costs for the government

However, those arguments are not valid. First, using a wind-weighted average for the entire Danish wind fleet will not distort the incentives for the developer to seek to capture the highest prices on the spot market. This is illustrated in Figure 7, where it is shown that using wind-weighted average prices only changes the level of the CfD, and not the incentive to capture higher prices. This is true as the revenue for the production in this auction design is equal to the power price *plus* the difference between the wind-weighted average price and the CfD bid with a weighted average. Thus, the value of the production can be maximized by capturing the highest possible spot power prices.

Figure 7
Illustration of incentives for maximizing captured prices
DKK/MWh



Note: Prices for 1 week 2020, DK1
Source: Energinet, spot prices for DK1, 2009

Furthermore, it can be illustrated that the expected costs of using a wind-weighted average price for the entire wind fleet as the reference price will not affect the State's expected subsidy costs. The reason is that if the developer expects the true captured prices to be lower than the reference price, as set out in the public auction design, the developer will just adjust their CfD-bid upward accordingly, as illustrated in Table 2.

Table 2
Comparison of CfD bids with average or wind-weighted reference prices

REFERENCE PRICE MODEL	YEARLY AVERAGE ("NAIVE BID")	YEARLY AVERAGE ("INFORMED BID")	YEARLY WIND-WEIGHTED AVERAGE
LCOE	300	300	300
CfD bid price	**300**	**321**	**300**
Reference price	213	213	192
Actual annual settlement	192	192	192
Subsidy	87	108	108
Income	279	300	300
	LCOE > revenue	**LCOE = revenue**	**LCOE = revenue**

Source: Copenhagen Economics, illustrative

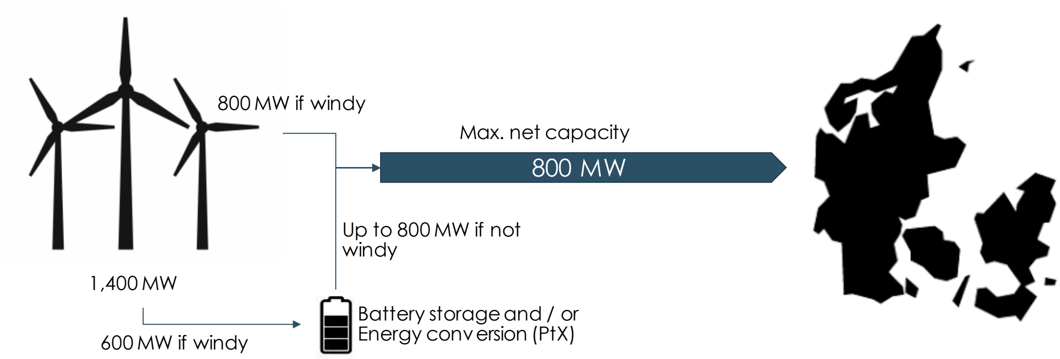
5 ALLOW FOR OVERPLANTING

The final element recommended as part of an optimized auction design for offshore wind is enabling flexibility in the design of the offshore wind farm by allowing for so called 'overplanting'. Overplanting is a situation where the auction does not decide a cap on how many MW the winner of the auction is allowed to install in the assigned area, but only defines the grid capacity at the connection point, thus allowing for an economic optimisation which could lead to a plant with a capacity larger than the grid capacity ('overplanting').

For offshore wind to be determining the long-term electricity price, we need to allow market players the possibility of producing more offshore wind. This could be by allowing 'overplanting' of the specific areas being auctioned, or further build-out in new areas identified as suitable for offshore wind farms, if the developer can handle grid connections and/or convert the power to other energy carriers onsite or inland, with or without connection to the grid.

In a situation with overplanting, we allow the best and cheapest sites for offshore wind farms to be used to their full extent based on an unrestricted optimisation of the business case. The limitations for offshore wind farms and their production is often the capacity of the grid – in other words, an offshore wind farm cannot and should not produce more than the capacity of the grid – if the power is to be delivered directly to the grid. However, many offshore wind farms could potentially produce more than the capacity of the grid, and this should be utilised to its fullest at the best sites. By overplanting, we use the resources available at the wind farm. Over-planting will thereby also help developers to achieve economic optimisation by allowing them to freely choose the number of wind turbines and capacity. For example, it can be cost efficient to install more MWs, well aware that in high wind periods some production would need to be curtailed, but over a year the overplanting can increase the MWh's produced and increase full-load hours.
With overplanting the developer can, in principle, build as much wind capacity as possible, and the excess electricity produced in windy periods can either be curtailed, stored in batteries or converted to other forms of energy. In periods with less or no wind, the batteries will release some of the excess electricity into the grid, see Figure 8. In this situation, the offshore wind farms are used more efficiently, and the grid receives a steadier supply of renewable electricity at all times.

Figure 8
Illustration of over planting



Source: Illustration by Copenhagen Economics

Seen from the perspective of the energy system/society, an overplanted wind farm will be delivering more stable production with more full-load hours, thus better utilizing the grid capacity. Furthermore, the produced energy will be capturing higher prices on average, thus allowing for lower bid-prices and thereby reducing the subsidy expenditures or increasing the CfD revenue for the State. Overplanting is a natural and appropriate response to the incentives of hybrid CfD auction designs.

Seen from a socio-economic perspective, a CfD auction design with the possibility of overplanting constitutes a much more attractive alternative to concession payments, as instead of paying taxes, the investment will be directed towards producing more green energy and thus lowering electricity prices for consumers. For example, a concession payment of 1 million DKK pr. MW will increase costs for the developer by 1 billion DKK. Without concession payments, the developer could instead use the 1 billion DKK to build additional capacity, including storage and/or energy conversion capacity, which would increase the renewable energy production and the socio-economic value of the produced power.