Department for
Business, Energy
& Industrial Strategy

Investment trends IN UK REnewable electricity Landscape

A report by Technopolis Ltd, LCP, and the University of London

Part of the CfD Evaluation Scoping Report

June 2019

Contents

Glossary

BEIS	UK Department for Business, Energy and Industrial Strategy
BNEF	Bloomberg New Energy Finance
CfD	Contract for Difference
FiTs	Feed in Tariffs
Gearing ratio	The ratio of debt to debt+equity in a project
IREA	International Energy Agency
IRENA	International Renewable Energy Agency
LCOE	Levelised Cost of Electricity
O&M	Operating and maintenance cost
PPA	Power Purchase Agreement
RECAI	Renewable Country Attractiveness Index
REmap	Renewable Energy Roadmap scenario of IRENA
RES	Renewable Energy Source
RO	Renewable Obligation
Utility	A company providing power, heat or water
Yieldco	Yield company, owning already operating assets, such as a power plant

Executive summary

This study was carried out as part of the scoping phase of the evaluation of Contracts for Difference (CfD) scheme, to provide an assessment of investment trends in UK Renewable Energy Sources (RES). The project was commissioned by BEIS and carried out during summer 2018 by a consortium of Technopolis, LCP, and the University of London. The lead author was Dr Gregor Semieniuk based at the University of London. It analyses the characteristics of RES investments and addresses three questions:

- What has RES investment in the UK looked like in the recent past?
- How do CfD project costs and hence investment needs evolve?
- Who are the investors and do they differ between RO and CfD projects?

Answers to these questions aim to make progress toward the bigger question: do investment trends point to a subsidy free[1] future for renewable energy provision, and what, if any, role in such trends can be ascribed to the CfD? The analysis is primarily based upon data sourced from the Bloomberg Terminal, which provides information on the financial structure of renewable energy projects. The report begins with a more general discussion of investments into RES generation to provide contextual background on the rationale for subsidies, with a focus on the UK, based on a scoping review of known sources and existing literature.

Summary of Findings

Investment trends in UK renewable energy

- The UK is a relatively late-coming champion for investment into renewable energy sources (RES) in Europe. The most recent data shows a relative drop in investments since 2016. Until more CfD volume is auctioned off, it is unlikely that investment will recover as investment without subsidy extends only to a handful of projects so far.

- CfD auctions have contributed to improving the cost-effectiveness of offshore wind, biomass & waste technologies, however only time will show if they are also effective in delivering the capacity at the low clearing prices.

- It is too early to infer whether this trend leads to a subsidy free generation in the near future. This is because the LCOE of RES depends on the subsidy's existence itself and higher penetration of RES may alter electricity prices. However, there are now reports of some subsidy free solar PV and onshore wind projects being implemented.

[1] 'Subsidy-free' can be defined in a number of ways. In this context we are using it to describe a deployment without any government backed, generation-based contract.

The profile of investors in CfD and non-CfD subsidised projects

- The first CfD round for onshore wind attracted a large number of successful bids made by strategic equity investors from the energy sector (66% of projects), of which 26% went to utilities and 40% of projects went to project developers.

- Offshore wind is developed by a small set of companies with a high share of state-backed actors including the Green Investment Bank and its successor. The type of investor varies little between RO and CfD projects, although there appears to be a higher proportion of investment coming from utilities in CfD projects. Individual utilities tend to finance much larger shares of individual project than other actors.

- Where project finance allows insight into debt financing sources, the data shows that state banks are often involved in the lender consortium. This suggests that investments into offshore wind have benefitted from RO or CfD schemes in tandem with direct public investment support, possibly at concessional rates and with guarantees.

- Information on investment characteristics for other technologies, in particular biomass and waste, is currently scarce.

Introduction

This study was carried out as part of the scoping phase of the evaluation of Contracts for Difference (CfD) scheme, to provide an assessment of investment trends in UK Renewable Energy Sources (RES). The project was commissioned by BEIS and carried out during summer 2018 by a consortium of Technopolis, LCP, and the University of London. The lead author was Dr Gregor Semieniuk based at the University of London. The report analyses the characteristics of UK Renewable Energy Sources (RES) investments to addresses three main questions:

- What has RES investment in the UK looked like in the recent past?
- How do CfD project costs and hence investment needs evolve?
- Who are the investors and do they differ between RO and CfD projects?

Answers to these questions aim to make progress toward the bigger question: do investment trends point to a subsidy free future for renewable energy provision, and what, if any, role in such trends can be ascribed to the CfD? The analysis begins with a more general discussion of investments into RES generation and the rationale for subsidies with a focus on the UK case.

Financing high-risk, capital-intensive investments in renewable energy

Renewable energy power plants are characterised by high upfront capital expenditure and the cost of financing it. These costs are only gradually recovered over the project's lifetime. Conversely, operating expenditure is low especially for wind and solar technologies with costless fuel. For instance, the International Energy Agency (IEA 2017a, p. 50) estimates that for an offshore wind power plant, about one third of the Levelised Cost of Energy (LCOE) comes from capital expenditure[2], one half from the cost of financing these. These financing costs arise for the capital supplied to make the investments: either as interest on loans or bonds, or as the return on equity. The former is a real cost, the latter an opportunity cost (Ondraczek et al. 2015). That is the plant's equity owners 'require' a certain return on their investment so as to perceive it worthwhile pursuing instead of other projects or opportunities (e.g. building a gas power plant). The remaining 20-30 per cent are operating and maintenance costs (O&M). For onshore wind, operating and maintenance costs represent an even lower share. These compare with a higher O&M and fuel cost share of 31-60% per cent for combined cycle gas power plants (Lazard 2017). The RES cost structure implies that RES project sponsors must assemble considerable financial resources at the outset and prove to investors that they are able to pay for them.

[2] Of this capital expenditure, about 40-60% go towards the wind turbines, the rest to offshore wind foundations (15-30%) and installation costs (10-25%) (IEA 2017, p. 50) .

Attracting the volume of investment necessary to meet carbon emission targets has proved a challenge for RES projects. A lack of finance for their high capital expenditures have been identified as one of the bottlenecks of RES expansion both globally, as acknowledged for instance in the Paris agreement (COP21), and in the UK, as a recent parliamentary report highlights (HC Environmental Audit Committee 2018). The International Renewable Energy Agency (IRENA 2018a) estimates in its Renewable Energy Roadmap (REmap) scenario, that global investments into RES have to more than double from current levels to 2050 in order to finance the more than sixfold faster expansion of RES consistent with two degree warming scenarios.[3] For the UK, a Green Alliance analysis of the UK Infrastructure Pipeline, an overview of large planned infrastructure projects published by the Treasury, suggests that UK clean energy investments may fall by 2020 to only 5% of the 2017 level (Green Alliance 2016). Clearly, to meet carbon emission targets through an energy sector transition, investment volumes have to increase.

The immature nature of several technologies (such as the ‘less established’ technologies under the UK CfD) further increase financing costs. The expense structure with high upfront costs and long payback horizons make investments particularly risky to the point where commercial investors are unwilling to make them. One way of addressing the financing challenge is providing subsidies. Policies like the CfD address financing costs in two ways. First, they shift the risk-return profiles by raising revenues relative to costs so as to facilitate investments. Secondly, they are also likely to help lower costs in the medium term. Technology costs have been shown to be negatively correlated with cumulative production/investments into the technology for a wide range of technologies (Farmer & Lafond 2015). This pattern also holds for RES technologies (Trancik et al. 2015). So to the extent that investment take place thanks to subsidies, the subsidy schemes help bring about subsidy-free RES provision by lowering costs until they are lower than unsubsidised revenue.

The rest of this report gives a high-level overview over recent aggregated UK investment trends situated in the European context. It then analyses in greater detail the cost trends in renewable energy, and any influence the CfD may have had on them. Finally, it studies the type of investors behind projects, and whether they differ between RO and CfD schemes.

[3] Part of the investment need is met by continually falling costs of RES technologies.

Investment Volume Trends

Balance Sheets, Projects and Disclosure

Historical and current investment into RES generating plants is typically financed in one of two modes: Balance sheet and project finance. In balance sheet financing, the asset will appear in the investor company's accounts along with all its other assets and liabilities. To pay for the costs the investor can use its cash from retained earnings from its other operations but can also raise cash using by taking out loans or issuing new shares. Household spending financed from savings and loans, public financing from tax revenues and bonds, and investments made by holding companies, such as yieldcos, master limited partnerships and real estate investment trusts are also grouped under balance sheet financing (IEA 2018). Availability and terms of finance depend on business performance and creditworthiness of the entire corporate entity rather than on an individual energy project.

Project finance instead treats the power plant as a separate legal entity, a special purpose vehicle. The project has a balance sheet that is separate from the equity sponsor's balance sheet. The risk of the project is shared with the lenders and less frequently bond holders of the SPV, with a ratio of debt to debt+equity, called gearing ratio, often exceeding 85% (Alonso 2015). This implies that lenders take on more than 85% of the cost of investment, a ratio that is significantly higher than in corporate finance. Project debt financing is a fixed-income instrument which relies solely on the ability of the project cash flows to repay the amounts borrowed. It typically has no recourse to its shareholders and is only secured against the assets and revenues of the project. Transaction costs for evaluating the SPV's cash flows and costs are significantly higher than for balance sheet finance. This is because all a potential lender can rely on is the project's performance (Steffen 2018). The economic rationales for pursuing project finance nonetheless are variegated (ibid). The standard reason given is that for larger projects, the additional transaction costs are outweighed by benefits from the large amount of debt with its lower interest rate. For instance, Lazard (2017), a major evaluator of the cost of RES, assumes 8% return on debt, and 12% on equity 12%. Project finance can thus reduce the cost of financing and make large investments more feasible (Alonso 2015).

In practice it is difficult to say how renewable energy finance is composed because of a lack of disclosure. Thus, while Bloomberg New Energy Finance (BNEF), a well-known data collector for RES investments estimates 42% of the deals in 2017 globally to be project financed, the IEA estimates this figure at only 20%.[4] In the UK, the share of investments channelled through project finance is higher than this global average, at least for disclosed

[4] Part of the difference may come from IEA's inclusion of large hydro power plants, which BNEF excludes, but it is not clear a priori that large hydro projects are balance sheet/government financed.

transactions. Figure 1 shows that more than half of disclosed investments were made via project finance in 2014-2017 on average regardless of technology financed. However, the financing of two thirds of UK investments transactions over this period remains undisclosed. Since it is more likely for project finance deals to disclose their transactions, as banks often issue press releases about their involvement (Steffen 2018), the actual share of project finance is likely to be lower.

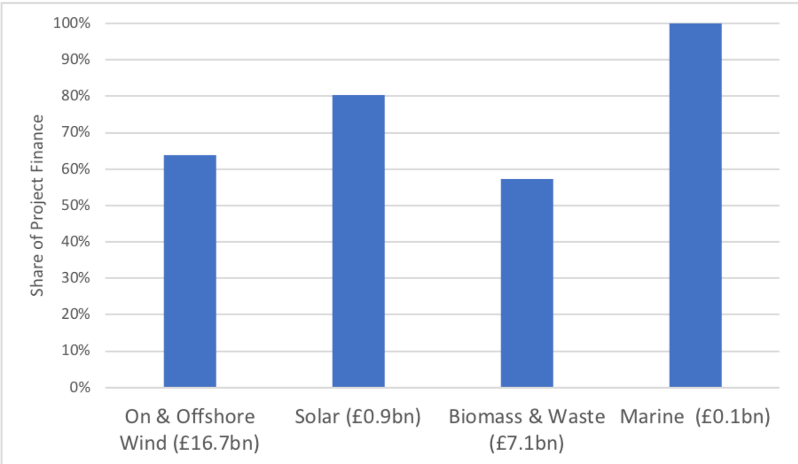


Figure 1: Project finance share of disclosed investment transactions in four RES sectors in the UK and disclosed volume in parentheses for project finance 1Q2014 through 1Q2017.

Source: Author's calculations based on Bloomberg Terminal.

Investments Volumes and Policies in the UK

In contrast to roughly constant or growing global investments, the rates of European investment into renewable energy have been falling since their 2011 peak (Figure 2). The complete collapse of the Spanish investments after 2012 due to retroactive reductions in subsidies plays an important role in this (Mir-Antigues 2018), but even more important is the simultaneous reduction in Germany and Italy in 2012. In that year German FiTs were reduced, and the German state bank, KfW, lowered its volume of concessional loans in 2012. Italy paid the same level of FiT from 2005 through 2010 that attracted strong investments after 2008 and led record subsidies on new solar PV installations. But support levels were lowered in 2011 and replaced by auctions in 2013 (Mahalingam and Reiner 2016). France has invested less in new RES than its peers, although long-running support policies have led to steady flow of investments into onshore wind and more recently solar PV. France's ambitions to reduce its big share of electricity from nuclear power while meeting EU emissions and renewable energy targets will require a steep increase in investments (IEA 2017c).

Among large Western European countries, the UK emerges as an atypical case: investments picked up just as they were falling elsewhere. UK investment more than doubled in 2009, the year the RO banding was introduced making investments into less established technologies more profitable. They stayed at about that level and then rose quickly from 2012 to 2015. In 2015 and 2016 the UK overtook Germany in investment volume for two years, before falling sharply in 2017. The drop coincides with the phasing out of the RO for solar and onshore wind in 2016, and other technologies in early 2017.

Judging from similar experiences with the threat of tax credits discontinuations in the US (BNEF & Business Council for Sustainable Energy 2017), it is likely that at least some of the growth in 2015 and 2016 reflects a rush for RO projects before the cut-off date. Moreover, given 2019 is the date for the next CfD round, which is now the only support mechanism for utility scale RES, combined with deployment caps on small scale RES systems (IEA 2017b), it is likely that UK investment in 2018 will be lower than in 2017. In fact, compared to the first quarter of 2017, UK investments in the first quarter of 2018 – not shown - dropped by about 50% (BNEF 2018). These trends show that investment into RES continues to be driven strongly by RES subsidy policies, and this is true also for other regions (IEA 2018).

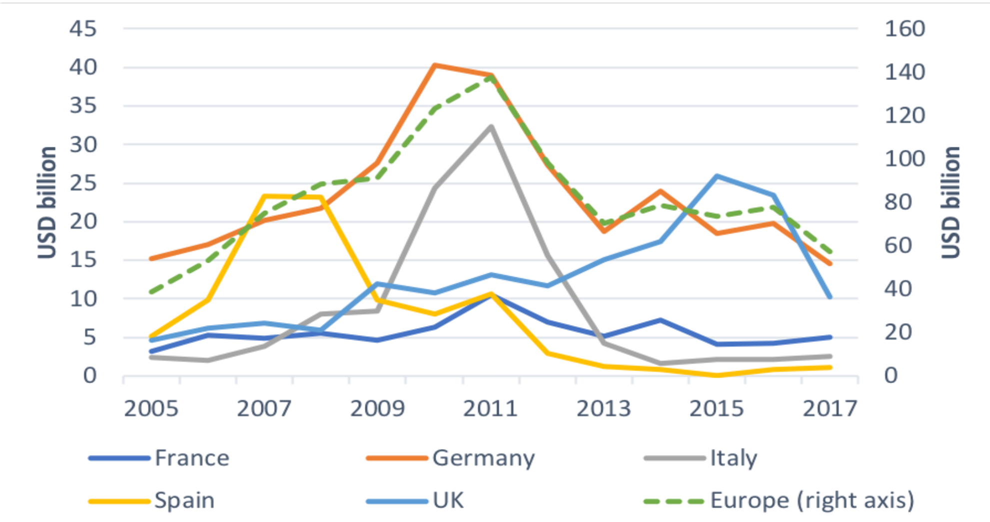


Figure 2: Annual investments in RES in major European countries (left axis) and Europe as a whole (right axis) in nominal USD for 2005-2017

Source: Author’s calculations based on BNEF 2018.

Although investment figures are unavailable for the smaller European countries, a look at capacity additions reveals that Denmark, an early wind power pioneer (Meyer 2004), is one of the most important players in RES installations. Figure 3 displays new net capacity installations *per capita* for comparability between countries. Except in 2006-07 when a large amount of old biomass capacity was retired, Denmark had a fairly steady rate of RES capacity additions (with peaks from commissioned offshore plants) and high net rate of installations. In the Netherlands meanwhile installations have picked up more recently, not completely unlike in the UK.

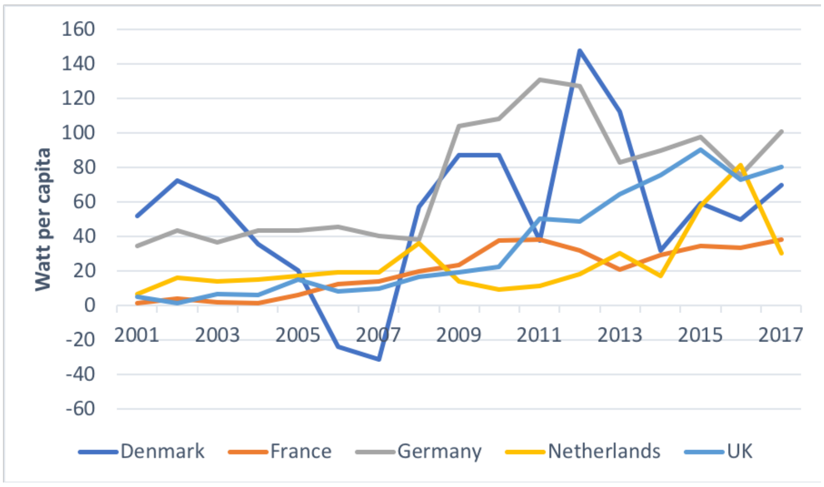


Figure 3: Per capita annual net RES capacity additions (excluding hydro), selected countries, in Watt per capita per year. The negative Danish data arise from biomass plant retirements.

Source: IRENA 2018, Eurostat 2018

Capacity lags investments

Commissioning of new generating capacity lags behind financing, as planning, construction and grid connection can take several years.[5] Investments are therefore a lead indicator of future capacity additions. For the UK, Figure 4 shows that while investment and capacity additions have a strong relationship, capacity additions are frequently foreshadowed by investments. Thus the 2009 doubling in investments (here in GBP) was only followed by a major uptick in capacity additions by 2011. Investments and capacity then grow together, partly thanks to large increases in small scale capacity where financing is recorded in the same year as commissioning. However, investment grows much faster than capacity in 2015, sustaining high rates of capacity additions through 2017, while investments fall by slightly more than 50%.

In its medium-term market outlook, the IEA (2017) forecasts UK capacity additions to 2022, also shown in Figure 4. This is based on CfD additions for onshore and offshore wind, and biomass and waste. Capacity from future CfD rounds is assumed to only generate electricity past the forecasting horizon of 2022. The reduction in FiTs for small-scale solar PV and the lack of further allocation rounds for Pot 1 “Established Technologies”1 including onshore wind and solar informs the estimates for further additions for those technologies. Clearly changes in capacity additions again lag the reduction in investment with by a couple of years. Of interest is the IEA’s forecast that

[5] When financing is undisclosed, data collectors such as BNEF assume a project reaches financial close when construction begins.

onshore wind will not be sustainable without policy support in England through 2022, due to low wind speeds but that some subsidy-free onshore capacity may come online in Scotland (IEA 2017b, p. 67).

The IEA also cautions about headwinds to investment in the wake of the Brexit referendum, as foreign components and labour have become more expensive with the pound exchange losing against other currencies. And while UK labour and components have become cheaper for foreign investors, the uncertainty about the outcome of the negotiations with Brussels may act as a detractor to potential investments. In sum, the UK has emerged as one of the major European investment destinations since 2009. However, the lack of pot 1 auction since Allocation Round 1 have been met with a relative drop in investment in the most recent past, and investment is likely to fall further, pending new support policies.

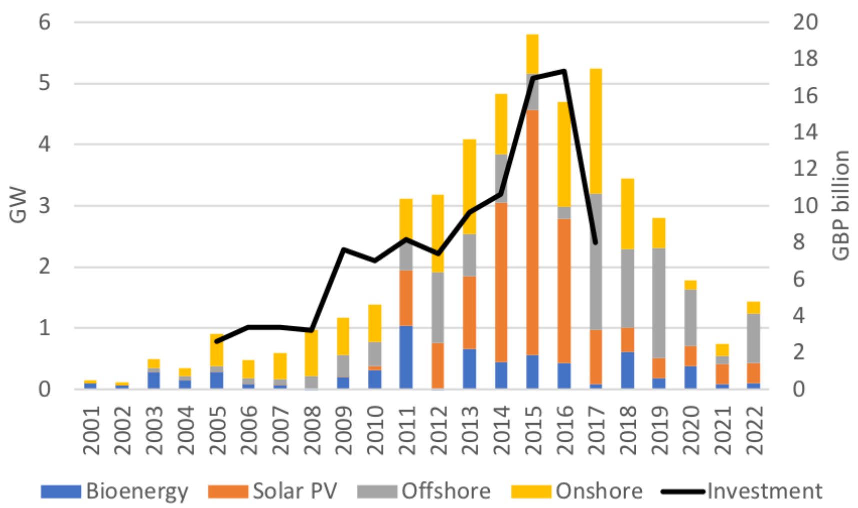


Figure 4: Annual UK RES capacity additions per technology 2001-2022 (forecast from 2018 and left axis), and investment in billions of current GPB for 2005-2017 (right axis).

Sources: Author’s calculations based on IRENA (2018b) for historical capacity, IEA (2017b) for forecast capacity, and BNEF (2018) for investments.

Investment Cost Trends

Investment needs are ultimately determined by costs. For RES, costs are typically measured in total installed costs or the costs per unit electricity generated, also called levelised cost of energy (LCOE) as the cost are levelled across (anticipated) lifetime generation of the asset (e.g. IRENA 2018c). Measuring total installed costs has the advantage that it does not rely on inferences about lifetime generation and financing cost. It therefore gives a fairly accurate picture of upfront investment needs and can also be used to infer investments (this is indeed how the investment figures in Figure 2 have been generated absent disclosed transactions). LCOE is attractive in that makes an estimate of *all* costs, also the significant cost of financing capital, and is measured in the same dimension as electricity prices: in £/Watthour.

More specifically, LCOE is calculated as the discounted costs of the project divided by its discounted revenues over its lifetime. This can be expressed as

$$LCOE = \frac{\sum_{t=0}^{T}(I_t + O_t + F_t + D_t)/(1+r)^t}{\sum_{t=0}^{T}(E_t)/(1+r)^t}$$

where, I is investment, O operation and maintenance cost, F fuel cost, D decommissioning cost, E energy generated, and r a dimensionless discount rate, which can be derived from the weighted average cost of capital. The weight refers to weighing the shares of equity and debt. Equity's hurdle rate[6] is typically higher than debt's interest rate. All costs and electricity are indexed by the time period, t, in which they occur and the discount is compounded by it. Reductions in costs straightforwardly lower the ratio, and so do increases in the load factor by increasing E. The cost of capital, expressed by the discount rate, influences LCOE as follows: the cost in the numerator is heavily skewed towards t=0 with I being the biggest magnitude. E on the other hand can be assumed evenly distributed.

Therefore a higher r disproportionately lowers the denominator, blowing up the ratio. As mentioned before, the cost of capital can account for half of LCOE. Hence changes in the cost of capital have a powerful influence on the price (and subsidies) needed by RES (Ondraczek et al. 2015). It is important to note that support policies such as the CfD – and certainty about its continuation – lower the required rate of return of the project and its LCOE. This is for the simple reason that certainty about revenue at a high enough level to break even significantly lowers the risk and thus the hurdle rates or interest rates that

[6] BEIS defines hurdle rates in its Electricity Generation Cost Report as the minimum project return that a plant owner would require over a project's lifetime on a pre-tax real basis (BEIS 2016).

investors require. Thus, LCOEs should be calculated contingent on the policy regime in place (Diacore 2016).

The LCOE estimate permits a comparison between current energy prices and the cost of renewables, and also between renewables and fossil fuels as it takes into account different load factors. CfD prices are also in this dimension, and LCOE information can supply useful information for analysing clearing prices in CfD auctions and give insights into the need for subsidies more generally.[7]

Under the CfD regime, clearing prices have fallen significantly across auctions. In offshore wind, the median clearing price fell by 20% between the early administrative CfD allocation and round 1, and a further median 52% on average between rounds 1 and 2. Figure 5 illustrates the decline in prices and shows how the latest auctions have come very close to bidding into the wholesale price band projected by BEIS (2017). The figure also correlates the clearing price with the expected generation start date. Strikingly, some round 2 projects are scheduled to start generating as early as the latest administrative CfD projects. Taking the median commissioning dates and prices of each auction round, the clearing price is falling at a compound annual growth rate (CAGR) of -12% from the early administrative to round 1 and at -28% from round 1 to round 2.

The rapid drop in offshore prices across auctions has also been observed in three Danish auctions in a time span of less than two years. The first project, Horns Rev III, that is under construction and to be commissioned at the beginning of 2019, won the bid at the equivalent to the CfD clearing price of 770 DDK/MWh in February 2015. Nineteen months later, in September 2016, the Vesterhav offshore farm bid came in 38% cheaper, started to commission at the end of 2020 two years after Horns Rev III. Only two months later, in November 2016, the Krieger's Flak winning bid was 52% cheaper than Horns Rev III and 22% cheaper than Vesterhaven, with the commissioning date set in 2022, only a year later. This translates into a compound annual growth rate (CAGR) of -17% across the three auctions. Further evidence for the rapid decline comes from the Dutch Borssele auctions both held in 2016 where the latter produced 25% lower winnings bids to be commissioned 15 months later, with a CAGR of -20%.[8]

This decline in clearing prices (summarised in table 1) across a period of only a few years in the British, Danish and Dutch offshore wind auctions is much faster than the long-term decline in offshore wind LCOEs hitherto. IRENA (2018c) estimates that offshore LCOE have fallen by 18% between 2010 and 2017, a CAGR of less than -3%. It appears that prices reduced at rates much faster than historical 'learning curves' in the recent auctions.

[7] The administrative strike price (price ceiling) set by BEIS for its auctions is also related to LCOE, but see BEIS (2016) for important additional considerations that flow into setting it.
[8] Data pulled from Bloomberg Terminal and BNEF Auction price sheet.

Table 1: Compound Annual Growth rate of clearing prices between auctions. Time period is calculated as the difference between announced commissioning dates.

	Median Price Change between auctions	Median Time Period between commissioning	CAGR
UK (round 1 & 2)	-52%	2.25 years	-28%
Denmark	-52%	4 years	-17%
Netherlands	-20%	1.25 years	-20%

One of auctions' major objectives is to improve RES cost-effectiveness and give regulators better control over subsidy volumes (Gephart et al. 2017; Kruger & Eberhard 2017). Key design elements are to increase competition and minimise overbidding (ibid.). While not all RES auctions held so far around the globe were successful in bringing down prices (ibid), the results for the British and other offshore auctions suggest that they largely achieved increased cost effectiveness. If the projects are commissioned, the CfD auctions will have contributed to lower offshore investment costs and the level of support payments per unit of electricity generated.

The other objective of auctions, however, is effectiveness in reaching desired capacity volumes. For this, auctions must also avoid underbidding and reduce risks for bidders (Kruger & Eberhard 2017). The projects with the low clearing prices in later auctions are not yet commissioned, and absent knowledge about the internal cost calculations of the project developers, the possibility of underbidding at least in some cases cannot be excluded. Some commentators have expressed the concern that auction prices could be too low for the projects to be delivered, and that the penalty for withdrawing under the CfD regime is mild, encouraging risky bidding (see especially the analysis by NERA 2017). In a related case, Ørsted and EnBW, the winners in a recent German 'subsidy free' auction,[9] were reported not to have made their final decision yet on whether to go ahead and invest in the project that is slated to be commissioned in the early 2020s (Hirtenstein and Morison 2017). The actual investment decision would depend on the offshore wind technology progress in the next few years.

It is possible for offshore wind projects to experience delays. . For example, the Neart Na Gaoithe farm, illustrated in Figure 5, had its expected commissioning date moved from 2019 to 2023, not due to technological problems, but to a legal challenge from the Royal Society for the Protection of Birds, highlighting that external factors can risk delays for large infrastructure projects (Vaughan 2017). For CfD round 2, however, so far there is

[9] In German auctions, the government pays for the connection to the grid, and thus offshore prices can be bid lower than in the UK where the developer must pay for the connection.

instead a ‘reverse delay’ with Ørsted bringing forward its expected Hornsea commissioning date. If these projects go ahead, Figure 5 shows that the cheapest two projects (Moray East and Hornsea Project 2) would be generating at costs only slightly above the high scenario wholesale price of BEIS’ projections (though a more relevant comparator would be the capture price for which a projection was unavailable at the time of writing).[10]

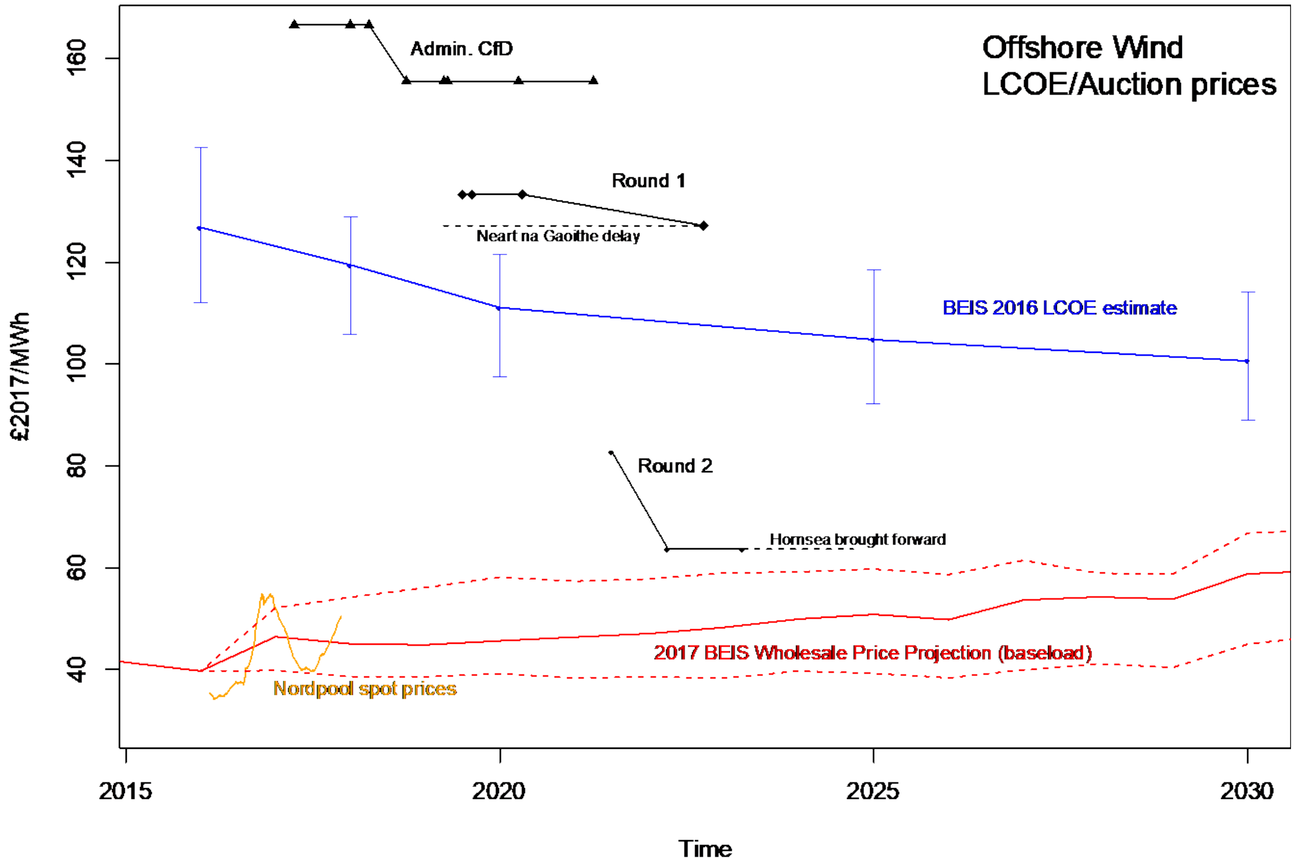


Figure 5: Offshore wind clearing prices plotted at date of expected generation start date for three CfD rounds; BEIS offshore LCOE estimate (inflated to 2017 prices), and historical spot auction and projected wholesale prices of electricity (dashed lines representing low and high estimates around a solid medium estimate).

Source: Author’s calculations based on BEIS 2016, BEIS 2017, Nordpool (2018), LCCC (2018)

[10] Care must be taken with the currency in which prices are compared. A 2017. Carbon Brief analysis (https://www.carbonbrief.org/analysis-uk-auction-offshore-wind-cheaper-than-new-gas) claims that ‘today’s £57.50/MWh offshore wind contracts are less than £5/MWh above the £53/MWh average wholesale price projected by BEIS for 2023-2035.” This compares apples with oranges as the £2012 prices of the CfD are compared with £2017 in the projection. In £2017 the offshore wind contract is at £63.66/MWh and thus more than £10/MWh more expensive than the electricity wholesale price.

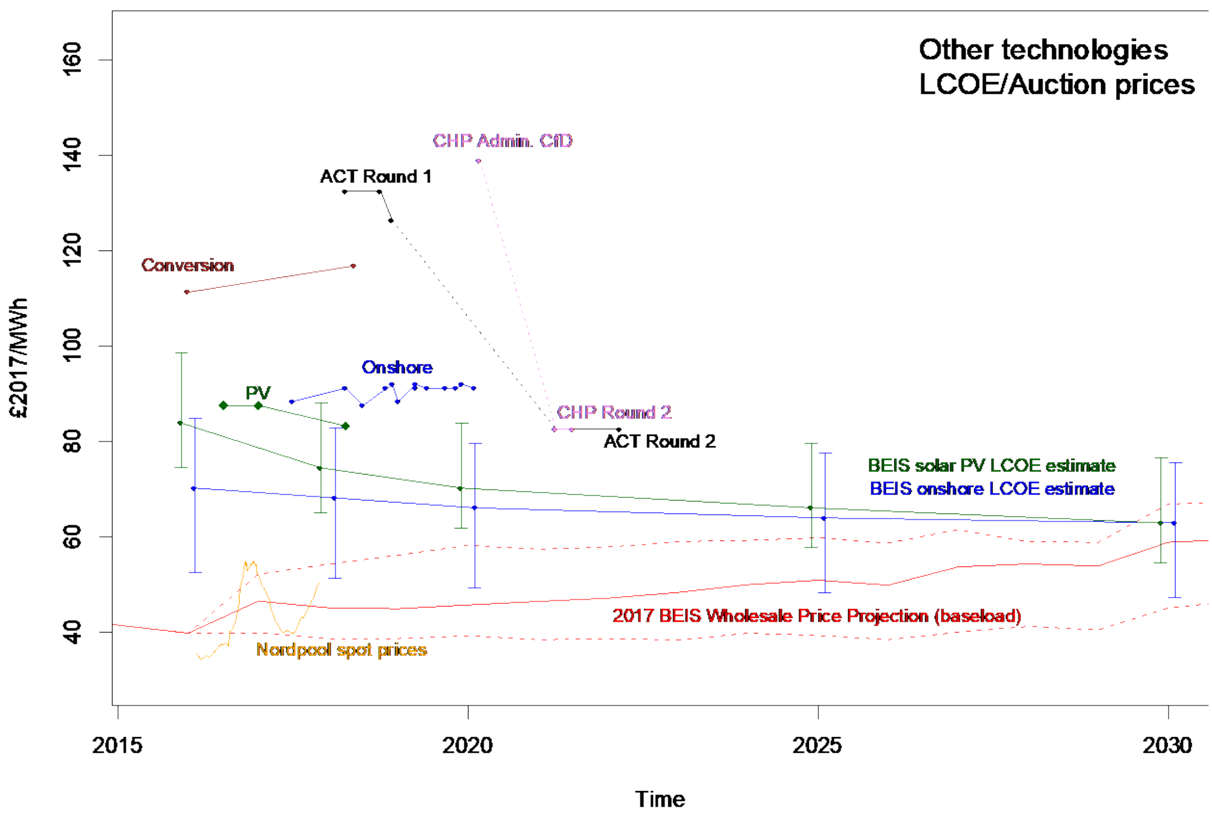


Figure 6: Clearing prices for all successful CfD bids except offshore wind plotted at date of expected generation start date; BEIS onshore and solar PV LCOE estimates (inflated to 2017 prices), and historical and projected baseload wholesale electricity prices (dashed lines representing low and high estimates around a solid medium estimate).

Sources: Author's calculations based on BEIS 2016, BEIS 2017, Nordpool (2018), LCCC (2018).

Other less established technologies have experienced reductions in prices on similar orders of magnitude, where a comparison is possible. As Figure 6 depicts, advanced conversion technology (ACT) prices fell on average by 37% between rounds 1 and 2, and dedicated biomass with CHP achieved a 41% clearing price reductions from the administrative CfD round. Clearing prices for the remaining technologies – onshore wind, PV, biomass conversion and energy from waste with CHP (not shown) – are available only for round 1 (or the administrative CfD for conversion) and so between-auction comparisons are impossible.

But comparing solar PV and onshore wind with BEIS' LCOE estimates for these technologies suggests that there may be price reduction potential and leads to the question of whether they could compete without CfD support already at present. The ability of onshore wind and solar PV to thrive without feed-in tariffs is particularly interesting against the backdrop of their exclusion from the second CfD allocation round, and announced exclusion from the 2019 auction under the clean growth strategy. The prospect of merchant wind power in Scotland,[11] has prompted Ernst and Young to upgrade the UK's ranking in their most recent RECAI (E&Y 2018, p. 10). According to Aurora Energy Research (2018) in spring 2018 there were five powerplants being developed in the UK without subsidies. Aurora also forecasts PV and onshore to become investible without subsidies by early to mid-2020s.

The CfD auctions have contributed to the reduction in prices. Evidence from the UK and elsewhere suggest that the auction mechanism played an important role in bringing down subsidies – and implicitly the cost of capital and/or investment costs. The more general question, whether this points to a subsidy-free future for renewables is difficult to answer however as the very existence of a subsidy can influence the cost of renewables. The existence of a subsidised power purchase agreement (PPA), such as the CfD, impacts the cost of capital. Moreover, if a considerable share of electricity is to be supplied from merchant variable RES (wind and PV), this can impact revenue negatively.

This is because market prices will tend to fall just when merchant RES supply increases: solar PV plants will generate most electricity on a sunny day, but that will be a period of low prices due to high solar PV supply. It has been estimated that intermittent variable RES may see their market value fall by as much as 50% (Hirth 2013, Hirth et al. 2016). This is because most of their electricity generated will occur precisely during periods where supply is highest and thus prices lowest. It implies that considerations of subsidy removal must account for more than only the auction vs market prices, especially for the more volatile RES

Moreover, integrating increasing shares of intermittent electricity from wind and solar energy can impose wider system costs. The authors of a UKERC report (Heptonstall et al. 2017) suggested that in a scenario where intermittent renewables (wind and solar) are providing 30% of electricity, increased systems balancing and integration costs could add around £10/MW. Complementary policies that notably increase grid flexibility are estimated to mitigate some of these costs (IEA 2018). The effects of subsidy removal on RES revenues and costs, as well as the impact of a higher RES penetration on electricity prices make projections of competitiveness highly contingent on assumptions.

[11] Merchant power plants produce electricity without a power purchasing guarantee and have to sell their power at the going market price.

Investor Participation Trends

The final section of this report investigates investor participation in RES projects, and whether there are any differences between RO and CfD investors. Investors can be classified along various dimensions. One is by their sector of activity. Utilities and energy project developers are called 'strategic investors' because their core business is in the energy sector. Other investors, in particular from the financial sector but also other sectors of the economy are 'financial investors' (Donovan 2015). Investors can also be classified by their risk appetite. High-risk, high-yield investors would invest in immature technologies, while more risk averse investors would invest in proven technologies (Hall and Lerner 2010, Demirel and Parris 2015).

Finally, investors can be classified into whether they are controlled by the public or private sector, and there is evidence of a correlation between high-risk and public investors: For less mature, high-risk technologies, private investors often follow the way paved by initial financing from public banks and other government agencies (Mazzucato and Penna 2016, Griffith-Jones and Leistner 2018). In particular, recent research suggests that on average publicly controlled investors, in particular publicly owned utilities and state banks, have been investing disproportionately into high-risk areas. These public agencies provide finance for projects that would not otherwise have been financed, rather than 'crowding out' private finance (Mazzucato and Semieniuk 2018). This finding has been confirmed for the case of the UK's Green Investment Bank in interviews with investors (Geddes et al. 2018).

Private companies undertake significant efforts to record and analyse RE investments. The most prominent players are Bloomberg New Energy Finance and Wood MacKenzie, but other companies also collect data, e.g. Ernst & Young, and a recent new source is Inspiratia. Public agencies such as IRENA and the IEA also collect data, but base part of their aggregate estimates on the previously mentioned commercial sources.[12] The main challenges for data collection is that many transactions are not disclosed, especially when they are balance sheet financed, and treated simply as part of the overall capital expenditure of a company. Therefore, the majority of transaction values, not to mention interest rates paid on loans, are not publicly known. For instance, Mazzucato and Semieniuk (2018) calculated that for about 56% of utility scale projects globally the amount of investment is unknown. Figures 1 and 2 above paint a similar picture for the UK. The volume of disclosed deals in Figure 1 is only a third of the estimated total investments in the UK into RES. In other words, an empirical analysis of investor identities and precise contributions, is difficult. Totals as calculated in the first Figure 4 above typically involve a significant amount of imputation – using capacity installed and average cost of the type of

[12] Additionally there are NGO-type organisations like the Climate Policy Initiative and REN21 that also collect additional data, and collaborate with some of the governmental organisations.

technology used. These difficulties notwithstanding, the rest of this report uses what data is available to examine how investor characteristics may vary between the CfD scheme and the RO.

Developers' characteristics

The best data is available for the equity providers as these own the project and can be identified regardless of whether the financing structure is disclosed or not. They are either developing the project themselves or are the equity providing parent companies of subsidiaries set up as the project's development companies. Owners can also change due to acquisition. The question of interest here is who are these equity investors, how do they finance their investments, and has any of this changed between the CfD and the earlier RO schemes. The further tentative question is whether changes in investment patterns, point to a reduction in risk.

Following Mazzucato and Semieniuk (2018), we record parent companies of equity owners at the time of financial close of the project and group them into broad categories depending on their industry, ownership and function. Applying their classification of investor types to the equity owns of the first round CfD onshore wind farms, and wind farms financed under the RO scheme in a comparable time frame, the following distribution emerges that is pictured in the pie chart in Figure 7. Under the RO scheme (left graph), twenty percent of projects are sponsored by firms whose main activity is the development of RES projects in the energy sector. These firms are labelled "energy firms". Another twenty percent is sponsored directly by utilities, and smaller shares are owned by non-bank financial institutions (FIN) such as asset management firms, and non-energy firm, non-utility and non-financial firms (NFF), such as retailers or manufacturing firms. A quarter of developers cannot be classified.

The most striking difference with the CfD scheme appears to be the larger share of energy developers participating in CfD projects. By contrast almost all other shares remain similar across RO And CfD projects, and the difference is made up by the much smaller share of unclassifiable developers. The small sample of CfD projects, the large unknown share under RO and the fact that some companies are active in several areas, however prevents the inference that energy companies, mainly companies specialised in developing RES projects, have increased.[13] Nevertheless, the data appears to show that the first CfD round attracted a large number of strategic investors from the energy sector that bid successfully, and that 40% of projects went to (on average) smaller project developers, rather than (on average) big utilities. This does not point to any particular change in risk profile between

[13] Thus half of the CfD 'energy firms' developed projects are owned by Banks Group Ltd, which also has a strong mining presence. It is grouped here as a renewable energy developer as it self-identifies as a project developer (it was classified as a financial company by Bloomberg).

RO and CfD but the question how strategic investors respond to the switch from RO to CfD might be worth following up.

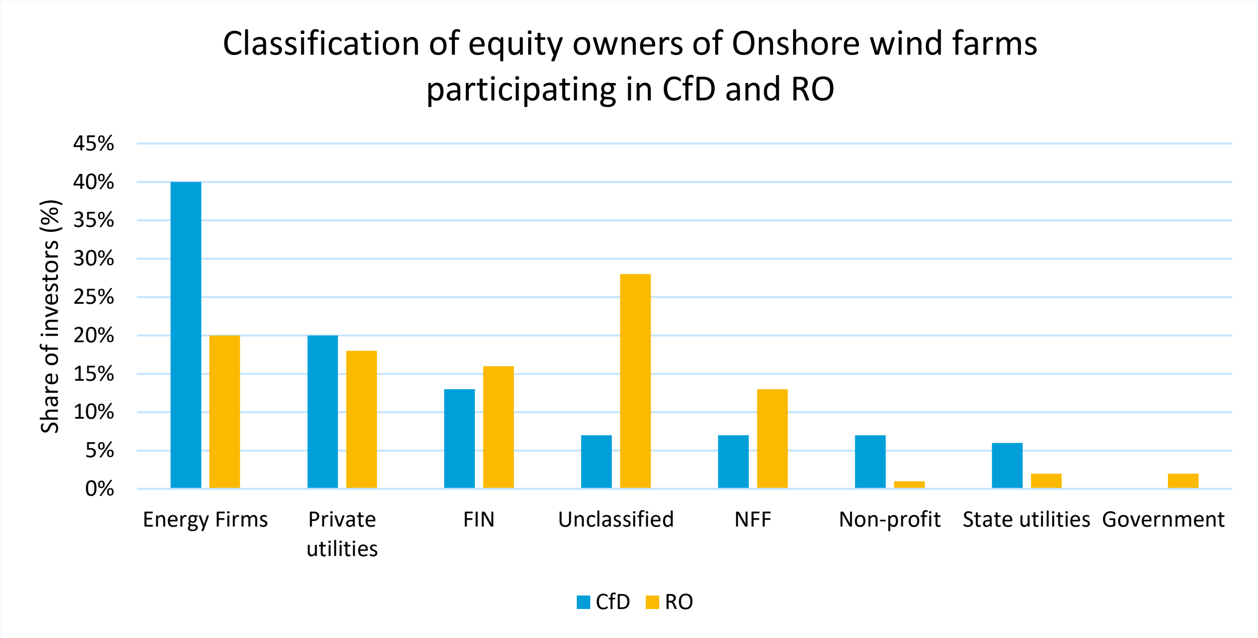
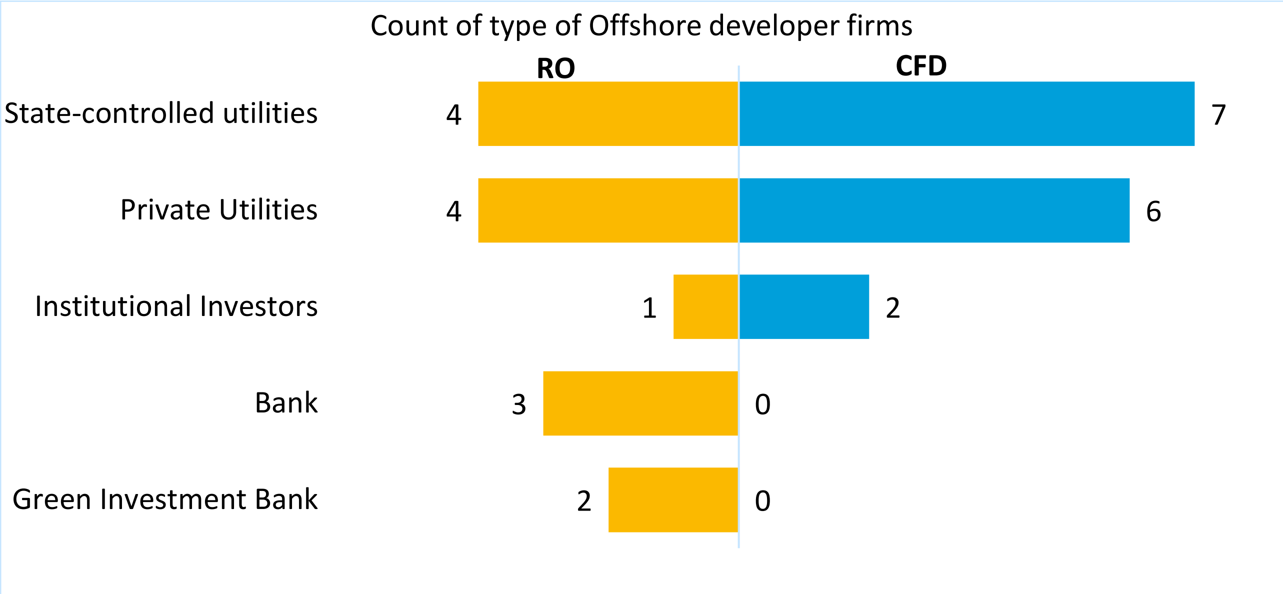


Figure 7: RO onshore windfarm equity providers with financial close estimated in 2014-early 2018, and CfD onshore windfarm equity providers (all in round one, with financial close typically in 2017-2018). NFF = non-financial, non-energy firms, FIN = non-bank financial firms, gov't = government agencies (classification as in Mazzucato and Semieniuk 2018).

Source: Bloomberg Terminal and February 2018, BEIS 2018.

Classifying offshore wind investors shows that a very different group of developers prevails in this technology. Figure 8 demonstrates that utilities make for the vast majority of project participations. Moreover, unlike for onshore wind, state-controlled utilities account for the largest share of project participations. Any non-utilities are banks or large institutional investors, and two of the three institutional investor participations involve a sovereign wealth fund. The former Green Investment Bank (GIB, now the privatised Green Investment Group) participates in two projects. The investor profile suggests that offshore projects are in a different capital intensity and risk class than onshore, while any differences between RO and CfD investors within offshore wind are difficult to ascertain.

Ownership matters, as state-controlled corporations are likely to be less risk-averse on average than private institutions thanks to their government backing (Roettgers 2018). Mazzucato and Semieniuk (2018) find that these corporations are more likely to invest in less mature RES technologies, and this is confirmed here when comparing offshore and onshore wind. None of the state-backed institutions except the former GIB are based in the UK. The latter's investment (into equity) only flows towards RO projects. One possible interpretation is that the CfD projects did not 'require' the GIB's help. However, CfD projects show a larger equity participation by state-backed utilities. Moreover, as the below analysis of project finance will show, CfD offshore projects also benefitted from state bank financing through non-recourse debt. It is more likely that offshore wind investors in both RO and CfD projects had access to different types of public support whether through the GIB, state-backed utilities or foreign state banks. Consequently, the CfD regime does not appear to attract a very different set of investors yet.



*Siemens grouped with banks (has a banking license).

**One of two is a sovereign investment fund.

***Statoil grouped with utilities.

Figure 8: Project involvement count of developer types (one project can have more than one developer).

Sources: Bloomberg Terminal, 4C Offshore.

The small number of investments into other technologies as well as poor insight into the developing companies makes a comparable exercise difficult for biomass and waste, and for solar PV. For offshore wind, however, the better data availability permits additional analysis of equity investments, including an estimate of total CfD investment flows and their share in overall offshore investment.[14] The resulting CfD financial headline data are displayed in Table 2, where the gearing ratio indicates that project finance has been used for the investment – here for four out of 10 projects. Subtracting the investment data from Table 2 from the overall annual investment estimates in Bloomberg (2018), yields the residual of investments made under a RO allocation. Figure 9 shows that while in 2015

[14] Investment volume data is available either from Bloomberg Terminal or 4C Offshore, and additional investigation into individual projects reveals most investment data, e.g. through company announcements, project websites or newspapers reporting on estimates by persons 'close to the project' (see e.g. Financial Times 2016). Reasonable imputations based on capacity can be made for a small number of projects where no data is available.

and 16, roughly half of investment flowed through CfD projects, from 2016 onwards virtually all projects that reached financial close were also CfD projects. This is in line with the closure of the RO scheme in March 2017 (projects commissioned prior to that receive 2 ROC per MWh electricity generated). The very large difference in annual investment volumes comes partly from the lumpiness (i.e. the large size) of individual offshore investments, and partly from the larger number of projects funded under the administrative CfD round and allocation round 1. Clearly, as long as the CfD is the only funding scheme for offshore wind, the CfD funding rounds will determine future investment volumes.

Table 2: Financial headline data for Offshore projects in all three CfD rounds, ND=not disclosed, an asterisk indicates high uncertainty/imputation. Source: Bloomberg Terminal, 4C Offshore, various newspapers and project websites.

Name of CFD Unit	*Round*	*Invest-m't £ bn*	*Gea-ring*	*Financial close*	*Strike Price 2012 £/MWh*
Hornsea Project 1 (3 phases)	Admin. CfD	3.3*	ND	2016	140
Dudgeon (3 ph.)	Admin. CfD	1.7	0.79	2014	150
Burbo Extension	Admin. CfD	1.2	ND	2016	150
Beatrice	Admin. CfD	2.6	0.65	2016	140
Walney Ext. (2 ph.)	Admin. CfD	2.7*	ND	2015	150
East Anglia One (3 ph.)	Round 1	2.5	0.26	2016	119.89
Neart na Gaoithe	Round 1	2.0	0.75	2016	114.39
Moray East	Round 2	2.2*	ND	2018	57.5
Triton Knoll	Round 2	2.0	ND	2018	74.75
Hornsea Project 2	Round 2	3.8*	ND	2017	57.5

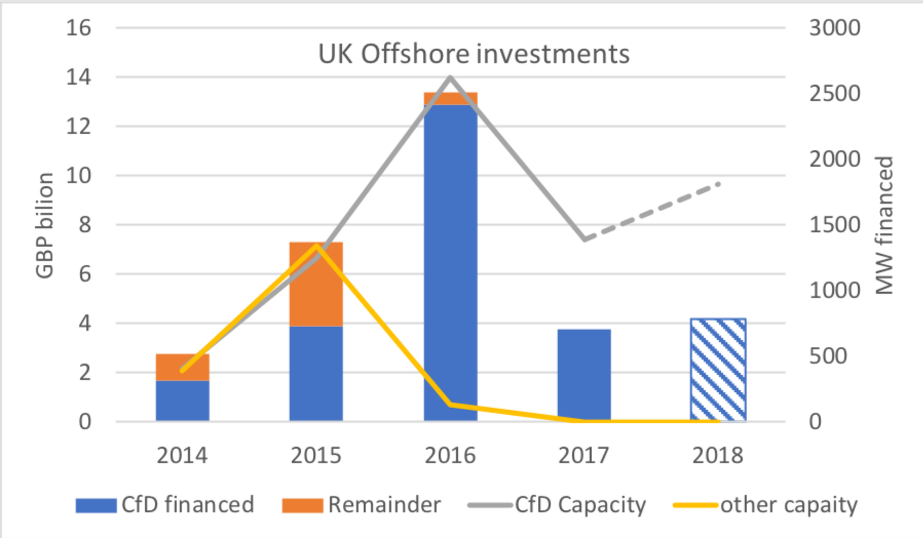


Figure 9: Amount of annual offshore finance in UK, and the share financed by CfD (left axis, bars), and the corresponding capacity that is financed in that year (right axis, lines).

Sources: same as Table 2 and various others for non-CfD projects. Allocation round 2 comprises investments in 2017-18. Note that 2018 financial close has been assumed for both remaining CfD projects, while no non-CfD project has been assumed to reach financial close in 2018. The RO offshore ‘remainder’ projects are 2014: East of Duddon; 2015: Galloper, Rampion, Race Bank, Hywind; 2016: Aberdeen, Blyth.

Although offshore wind projects financed between 2014 and 2018 are often owned by more than one investor, only sixteen organisations are involved in the ownership of the sixteen projects financed. This can shed some light on the universe of companies willing and able to participate in offshore auctions. As Table 3 shows, the Danish utility Ørsted participates in six projects and when it does, it owns on average 79% of all equity.[15] The table also shows that four of its projects are allocated a CfD. Except for Macquarie (counted above as a bank) and its acquired GIB projects, and E.ON, all companies involved in more than one project have at least one project with and without CfD. Nine companies only participate in one project. There is no clear pattern as to whether this is a CfD or RO project, nor whether companies’ involvement with CfD correlates with a low or high ownership share.

One pattern that does emerge from the last column of Table 2 is the larger share in individual projects that utilities own: Ørsted, Iberdrola, E.ON, RWE, Vattenfall, EDP and Statkraft all own on average fifty percent of more of the projects they develop. This contrasts with financial and other non-strategic investors, who typically own less than half of assets (with SSE and Engie being exceptions to the high share utilities).

[15] This calculation assumes each participant owns an equal share if undisclosed.

In sum, an analysis of equity investors into onshore and offshore wind has revealed that the onshore CfD contract appears to have attracted a higher share of strategic investors from the energy sector than the RO scheme. Offshore project owners are mainly large utilities, many of which are state-backed corporations. If financial investors participate, their share in a project is much lower on average, and overall a very small number of companies appears to have participated in offshore project development, whether with or without CfDs.

Table 2: Count of project ownership around financial close, the number of these with CfD allocation, and unweighted average ownership shares.

	Projects involved in	*of which CfD*	*Average share*
Ørsted	6	4	79%
*Macquarie Group (including GIB)**	3	0	40%
Mubadala Investment Corp	2	1	28%
Iberdrola	2	1	75%
Statoil	2	1	48%
E.ON	2	0	90%
RWE	2	1	63%
Vattenfall	1	0	100%
EDP	1	1	57%
Statkraft	1	1	50%
SSE	1	1	40%
Copenhagen Infrastructure Partners	1	1	35%
Siemens	1	0	25%
SDIC Power Holdings	1	1	25%
Engie	1	1	23%
Diamond Generating (Mitsubishi)	1	1	20%

*Two equity participations were originally by the Green Investment Bank (GIB), one in the same project as Macquarie's independent stake, before GIB was bought by Macquarie.

Source: Bloomberg Terminal, 4C Offshore.

Mode of financing

Another angle on the characteristics of investments emerges from looking at the mode of financing. Seven or roughly half of the fifteen onshore CfD investments are known to be project-financed, two are awaiting financial close, and six are under construction without further information about their financing structure. These are assumed to be balance sheet financed. Table 2 above identifies four out of ten CfD offshore projects as project financed. The Drax biomass conversion involves project finance, while the Lynnemouth conversion and the Grangemouth biomass plants are balance-sheet financed. These figures are similar to the overall share of project finance in recent UK RES investments (Figure 1), so the CfD appears not to have an influence on the mode of financing.

One advantage that project finance affords for analysis is information about the amount invested and who provides the debt finance. The results are briefly summarised: for onshore wind farms, debt of below £100 million is typically provided by only one commercial bank. One exception is a project finance deal that finances three wind farms (Kype Muir, Middle Muir and Moorland) at once: the debt amounts to £387 million, provided by a consortium of five commercial banks. Offshore wind projects (as well as the Drax conversion) are typically financed by a larger set of players.

The larger offshore farms are typically split into phases, each of which is financed (and sometimes developed) by a different debtor consortium. State investment banks or export credit agencies are often involved. State investment banks operate like a bank in that they lend money either at market or at concessional, i.e. below market, rates (and sometimes acquire equity like the GIB), but they typically have an industrial policy mandate from the government to push certain industries or technologies, rather than to maximise their profits in order to bring about economic development and structural change. This often targets projects that would not normally be financed by commercial banks, at least not on their own. In high income countries like the UK, the need for this arises in high-risk, innovative industries, such as offshore RES, and here state investment banks have been shown to crowd-in and mobilize private finance through their own participation (Geddes et al. 2018). Export credit agencies focus on activities of domestic companies abroad by guaranteeing the loans these companies take up for their investments abroad. In practice, in RES finance, they often perform functions similar to state investment banks. In the case of the UK offshore financed, their presence suggest that funding may have been difficult to attain without these investment-mobilizing agents.

An illustrative example is the Beatrice Wind Farm, for which detailed financing information is available (see Box 1) and shows that state investment banks not only participate in every debt tranche but also provide upwards of twenty percent of the entire investment volume. Other CfD projects also mention funding from the European Investment Bank (Neart na Gaoithe) or the KfW IPEX Bank (Walney Extension). No CfD round 2 project has disclosed financing details. For Ørsted, however, which finances the round 2 Hornsea project on its balance sheet, there is evidence from its earlier offshore investments that it has sold them on to acquirers with the help of concessional finance from the Danish export credit agency, EKF. Ørsted has also issued a green bond. One question that this raises is whether offshore bids purely from private players can compete with those benefitting in one way or another from public institutions, whether through concessional loans or guarantees.

Box 1: Financing the Beatrice Wind Farm

According to Bloomberg, financial close of £2687m for the Beatrice Offshore Wind Farm was secured in May 2016, two years after its administrative CfD allocation. The developers financed £939m or 35% of total costs with common equity. Another £1359m or 51% came from senior debt for the generation assets, i.e. investments into the windfarm construction, and £389m or 14% of the total in senior debt financed the transmission assets.

An unknown consortium of financial banks participated in one tranche of the generation debt of £764m together with the Danish export credit agency (EKF), and the European Investment Bank. One of the equity providers lent an additional £70m, and the European Investment Bank provided an additional £525m tranche by itself. A consortium of twelve commercial banks and the German export credit agency (KfW IPEX) financed the transmission asset loan. Public banks or export credit agencies thus contributed to each debt trance, and like financed more than a fifth of the project's investment.

The information about other technologies is less detailed, although the Drax Biomass Conversion reports a credit facility from two commercial banks and the Green Investment Bank already in 2012. Because of the small size of most biomass and waste projects, it is more likely that these have been balance sheet financed. In conclusion, less established technologies appear to rely on financing consortia where state investment banks are involved, while the more mature technologies, notably onshore wind, are able to secure loans with individual banks for financing their CfD supported projects. These patterns appear similar to financing schemes under other support schemes.

Conclusion

This report has reviewed recent trends in the investment landscape of UK renewable electricity projects, the cost of RES project investments measured in LCOE, and the type of investors and their financing modes.

The UK is a relatively late-coming champion for RES investment in Europe, yet recent data suggests there has been a drop in investments since 2016. Until more CfD volume is auctioned off, it is unlikely that investment will recover as investment without subsidy extends only to a handful of projects so far. CfD auctions have contributed to improving the cost-effectiveness of offshore and of biomass & waste technologies, however only time will show it they are also effective in delivering the capacity at the low clearing prices. Onshore wind attracts a variety of equity investors, and CfD has seen a high share of dedicated RES developers step forward. Offshore wind is financed almost exclusively by large utilities and banks and state-linked institutional investors, both under RO and CfD schemes. State banks are often involved in the lender consortium, implying additional support besides the CfD is occurring, e.g. through concessional financing rates.

A number of potential questions to address in future phases of the evaluation emerged:

1) How do the CfD auctions reduce prices? What are bidders rationales for bidding so low (compared with the previous round)?
2) How do strategic investors, in particular (smaller) project developers mainly focused on solar PV and onshore wind cope with the switch from RO to CfD and the lack pot 1 auctions since Allocation Round 1?
3) What are the UK ‘merchant’ projects without subsidies and without purchasing power agreement? How are they financed?
4) Does the CfD change the way that offshore projects are financed? Does it lower costs relative to RO? How? Could a consortium composed purely of private actors successfully bid for a CfD?

Bibliography

Alonso Ciruelos, A., 2015. "Project finance and the supply of credit from commercial banks." *RENEWABLE ENERGY FINANCE: Powering the Future*. 245-272.

Aurora Energy Research, 2018. Renewables 2.0: The subsidy-free revolution. Retrieved from https://www.auroraer.com/wp-content/uploads/2018/04/Renewables-2.0-Aurora-Spring-Forum-2018-Keynote-Presentation-1.pdf

BEIS, 2016. Electricity Generation Costs (November 2016).

BEIS, 2018. Renewable Energy Planning Database. Retrieved from https://data.gov.uk/dataset/a5b0ed13-c960-49ce-b1f6-3a6bbe0db1b7/renewable-energy-planning-database-repd

BNEF, 2018. Clean Energy Investment Trends, 1Q 2018. Bloomberg New Energy Finance. Retrieved from https://data.bloomberglp.com/bnef/sites/14/2018/04/Clean-Energy-Investment-Trends-1Q-2018.pdf

BNEF & Business Council for Sustainable Energy, 2017. Sustainable Energy in America: Factbook. Retrieved from https://data.bloomberglp.com/bnef/sites/14/2017/02/BCSE-BNEF-2017-Sustainable-Energy-in-America-Factbook.pdf

COP21. Decision 1/CP.21. Conference of the Parties, UNFCCC. Retrieved from http://unfccc.int/files/home/application/pdf/decision1cp21.pdf

Demirel, P. and Parris, S., 2015. Access to finance for innovators in the UK's environmental sector. *Technology Analysis and Strategic Management*, 27(7), pp.782–808.

Diacore, 2017. The impact of risks in renewable energy investments and the role of smart policies. Fraunhofer ISI. Retrieved from https://www.ecofys.com/files/files/diacore-2016-impact-of-risk-in-res-investments.pdf

Donovan, C. W., 2015. *Renewable energy finance: powering the future*. World Scientific Publishing Co. Pte. Ltd.

Ernest & Young, 2018. 'Renewable Energy Country Attractiveness Index: Issue 51'.

Evans, S. 2017. In-depth: The whole system costs of renewables. Carbon Brief, 22 February. Retrieved from https://www.carbonbrief.org/in-depth-whole-system-costs-renewables

Farmer, J. D., & Lafond, F., 2016. How predictable is technological progress? *Research Policy*, *45*(3), 647–665.

Geddes, A., Schmidt, T. S., & Steffen, B., 2018. The multiple roles of state investment banks in low-carbon energy finance: An analysis of Australia, the UK and Germany. *Energy Policy*, *115*, 158-170.

Gephart, M., Klessmann, C., & Wigand, F., 2017. Renewable energy auctions–When are they (cost-) effective?. *Energy & Environment*, *28*(1-2), 145-165.

Green Alliance, 2016. The UK's Infrastructure Pipeline. Briefing, December 2016. Retrieved from https://www.green-alliance.org.uk/resources/UK_infrastructure_pipeline_2016.pdf

Griffith-Jones, S., and Leistner, S., 2018. Mobilising Capital for Sustainable Infrastructure: The Cases of the AIIB and the NDB. German Development Institute. Retrieved from https://www.die-gdi.de/uploads/media/DP__18.2018.pdf

Hall, B. H., & Lerner, J., 2010. The financing of R&D and innovation. In *Handbook of the Economics of Innovation* (Vol. 1, pp. 609-639). North-Holland.

Hirtenstein, A, and Morison, R., 2017. Subsidy-Free Wind Power Possible in $2.7 Billion Dutch Auction. Bloomberg News, 17 December. Retrieved from: https://www.bloomberg.com/news/articles/2017-12-14/subsidy-free-wind-power-possible-in-2-7-billion-dutch-auction

Hirth, L., 2013. The market value of variable renewables: The effect of solar wind power variability on their relative price. *Energy economics*, *38*, 218-236.

Hirth, L. and Steckel, J.C., 2016. The role of capital costs in decarbonizing the electricity sector. *Environmental Research Letters*, 11(11).

House of Commons Environmental Audit Committee, 2018. Green finance: mobilising investment in clean energy and sustainable development. Sixth Report of Session 2017–19.

IEA, 2017a. Special Report: Offshore energy outlook. Paris: International Energy Agency.

IEA, 2017b. Medium Term Market outlook. Paris: International Energy Agency.

IEA, 2017c. Energy Policies of IEA Countries: France. Paris: International Energy Agency.

IEA, 2018. World Energy Investment. Paris: International Energy Agency.

IRENA, 2018a. Global Energy Transformation: A Roadmap to 2050. Abu Dhabi: International Renewable Energy Agency.

IRENA, 2018b. Capacity and Generation. Retrieved from http://resourceirena.irena.org/gateway/dashboard/

IRENA, 2018c. Renewable Power Generation Costs in 2017. Abu Dhabi: International Renewable Energy Agency.

HC Environmental Audit Committee, 2018. Green finance: mobilising investment in clean energy and sustainable development. Sixth Report of Session 2016-17.

Heptonstall, P., Gross, R. & Steiner, F., 2017. The costs and impacts of intermittency – 2016 update. UKERC.

Hirth, L., 2013. The market value of variable renewables: The effect of solar wind power variability on their relative price. *Energy Economics,* 38, pp.218–236.

Hirth, L., Ueckerdt, F., Edenhofer, O., 2016. *Why wind is not coal: On the economics of electricity generation.* Energy J. 37, 1–27.

Kruger, W. and Eberhard, A., 2016. 'Renewable Auctions in Sub-Saharan Africa', in *PFI EMEA Report 2016*, London: Project Finance International

Lazard, 2017. Lazard's Levelized Cost of Energy Analysis - Version 11.0. Retrieved from https://www.lazard.com/media/450337/lazard-levelized-cost-of-energy-version-110.pdf

Mahalingam, A. and Reiner, D., 2016. *Energy subsidies at times of economic crisis: A comparative study and scenario analysis of Italy and Spain*. Cambridge Working Papers in Economics.

Mazzucato, M., Penna, C.C.R., 2016. Beyond market failures: the market creating and shaping roles of state investment banks. J. Econ. Policy Reform 19 (4), 305–326.

Mazzucato, Mariana, and Gregor Semieniuk, 2018. "Financing renewable energy: Who is financing what and why it matters." *Technological Forecasting and Social Change* 127 (2018): 8-22.

Meyer, N.I., 2004. Renewable energy policy in Denmark. *Energy for Sustainable Development*, [online] 8(1), pp.25–35.

Mir-Artigues, P., Cerdá, E. and del Río, P., 2018. Analysing the economic impact of the new renewable electricity support scheme on solar PV plants in Spain. *Energy Policy*, 114(December 2017), pp.323–331.

Ondraczek, J., Komendantova, N. and Patt, A, 2015. WACC the dog: The effect of financing

Prag, A., Röttgers, D. and Scherrer, I, 2018. State-Owned Enterprises and the Low-Carbon Transition. *OECD Environment Working Papers* 129.

Steffen, B. 2018. The importance of project finance for renewable energy projects. *Energy Economics*, *69*, 280-294.

Trancik, Jessika E., et al., 2015. *Technology improvement and emissions reductions as mutually reinforcing efforts: Observations from the global development of solar and wind energy*. MIT, 2015.

Tsagas, I., 2018.The weekend read: Solar's coming of age in the UK. PV Magazine, 9 June. Retrieved from https://www.pv-magazine.com/2018/06/09/the-weekend-read-solars-coming-of-age-in-the-uk/

Vaughan, A, 2017. RSPB loses legal fight against £2bn offshore windfarm in Scotland The Guardian, 19 July 2017. Retrieved from https://www.theguardian.com/environment/2017/jul/19/rspb-loses-legal-fight-2bn-offshore-windfarm-scotland-neart-na-gaoithe

© Crown copyright 2022

This publication is licensed under the terms of the Open Government Licence v3.0 except where otherwise stated. To view this licence, visit nationalarchives.gov.uk/doc/open-government-licence/version/3 or write to the Information Policy Team, The National Archives, Kew, London TW9 4DU, or email: psi@nationalarchives.gsi.gov.uk.Where we have identified any third party copyright information you will need to obtain permission from the copyright holders concerned.

This publication available from www.gov.uk/beis

Contact us if you have any enquiries about this publication, including requests for alternative formats, at:

Department for Business, Energy and Industrial Strategy
1 Victoria Street
London SW1H 0ET
Tel: 020 7215 5000

Email: enquiries@bis.gsi.gov.uk