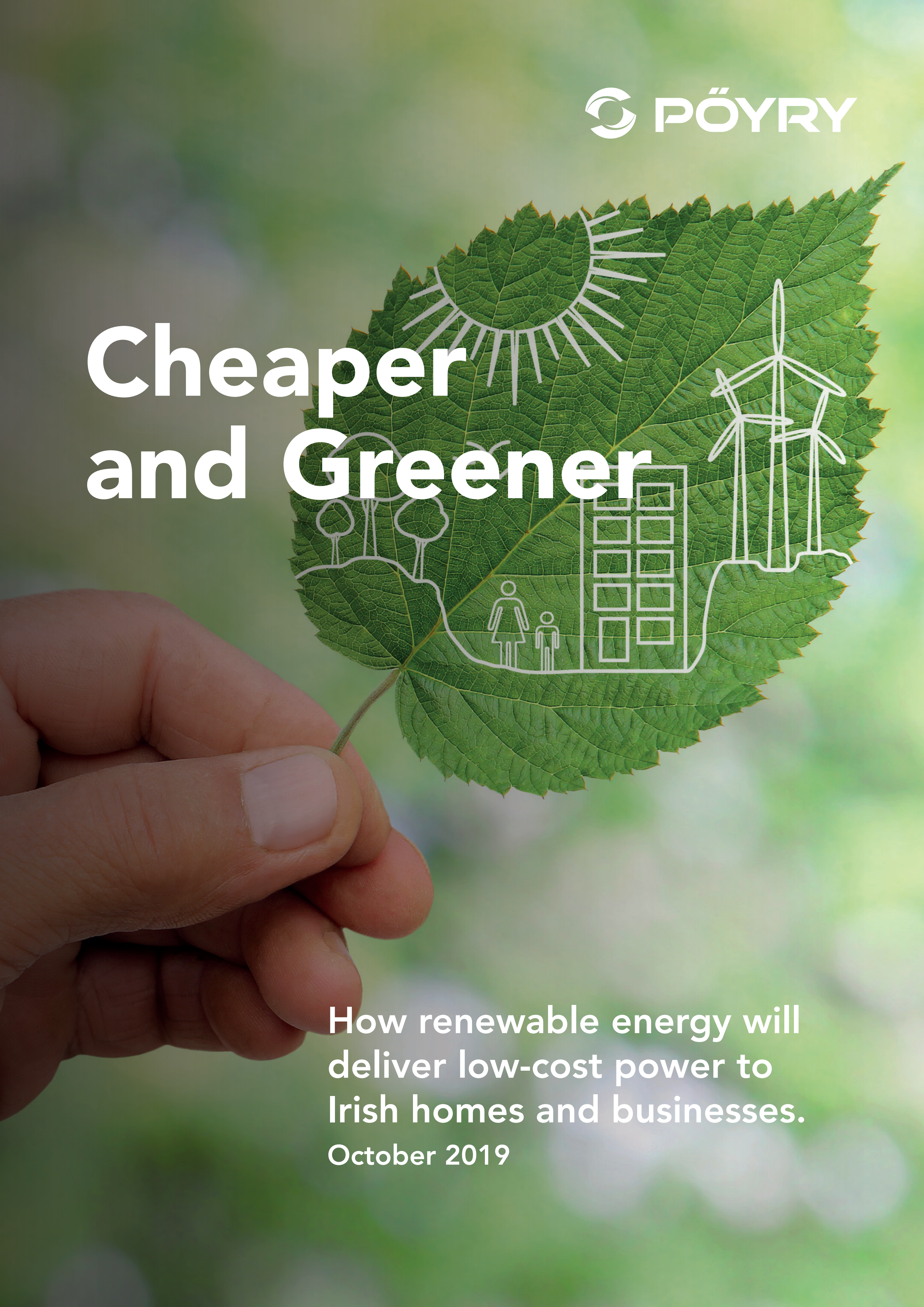

PÖYRY

Cheaper and Greener

How renewable energy will deliver low-cost power to Irish homes and businesses.

October 2019

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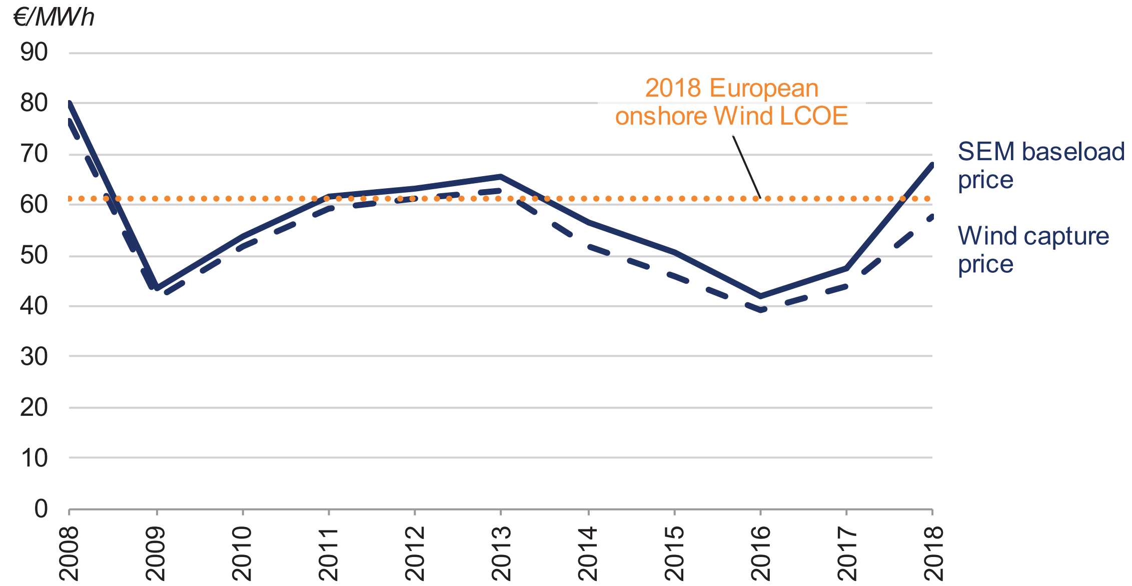
EXECUTIVE SUMMARY

Renewables never better value

Wind and solar power have never offered better value to consumers. In recent years, costs have fallen significantly, driven by (amongst other factors): efficiencies in the supply chain and technological improvements. These have driven the levelised cost of electricity (LCOE)[1] for renewables to levels well within the historical range of wholesale electricity prices seen in the Single Electricity Market (SEM) covering the island of Ireland (Figure 1). For example, in 2018, the International Renewable Energy Agency (IRENA) estimated the levelised cost of electricity (LCOE) from onshore wind in Europe at €61/MWh[2].

Figure 1 – Historical average wholesale electricity prices in the SEM (€/MWh, nominal money)



Note: The baseload price gives equal weight to all hours in a year and reflects the System Marginal Price in 2008 to September 2018 and the Day Ahead price from October 2018 onwards; the wind capture price weights each hour by the amount of wind generation available that hour.

Source: Wholesale prices – SEMO; wind capture prices – SEMO and EirGrid; onshore wind LCOE – IRENA.

Renewables thrive on stability

Relative to many other forms of electricity generation, renewable electricity has higher capital costs and lower operating costs. As a result, the cost of capital is an important commercial driver for renewable electricity prices. It is widely recognised that schemes that provide long-term predictable and stable pricing are successful in attracting low cost capital and delivering low cost renewables.

1 A measure of the lifetime costs of a technology divided by its lifetime output.

2 IRENA, Renewable Power Generation Costs in 2018, May 2019.

In the EU today renewables are sometimes seen to accept long-term prices below the wholesale electricity price because investors and lenders value price stability more than higher but unpredictable market prices. For example, in Spain today, solar projects are seen to enter long-term PPAs at below the wholesale electricity price.

Consequently, the term 'renewable support' does not necessarily mean a premium to wholesale prices and the term 'Revenue Stabilisation Mechanism' has been gaining more widespread usage.

Contracts for Difference (CfD), and specifically 2-way CfDs, where the renewable generator pays back when the wholesale price is above the agreed strike price are increasingly popular Revenue Stabilisation Mechanisms across Europe. Typically these take the form of government backed contracts, although they can also be found in some (i.e. financial) corporate power purchase agreements (CPPAs).

2.5 billion reasons to provide stability

Our analysis suggests that if CfD strike prices come in at €60/MWh[3] over the fifteen year period from 2025 to 2040[4], consumers in both Northern Ireland (NI) and the Republic of Ireland (ROI) could benefit by around €2.5B, on the basis of the assumptions behind the two pathways modelled (additional details can be found in Sections 2 and 3). This is outlined in Figure 2. The cost of providing stability to CfD-supported generators would be around €3.2B. However, reduced wholesale electricity prices would more than offset this cost, benefitting consumers by around €5.8B[5].

Although estimates of Net Consumer Value are sensitive to the price at which CfDs are struck, our analysis suggests that consumers will benefit across a wide range of plausible strike prices. Even at strike prices of €65/MWh, the net value accruing to Irish consumers would be almost €2B. Were strike prices to be in line with recent renewables auctions in Great Britain[6], consumers could benefit by close to €4B.

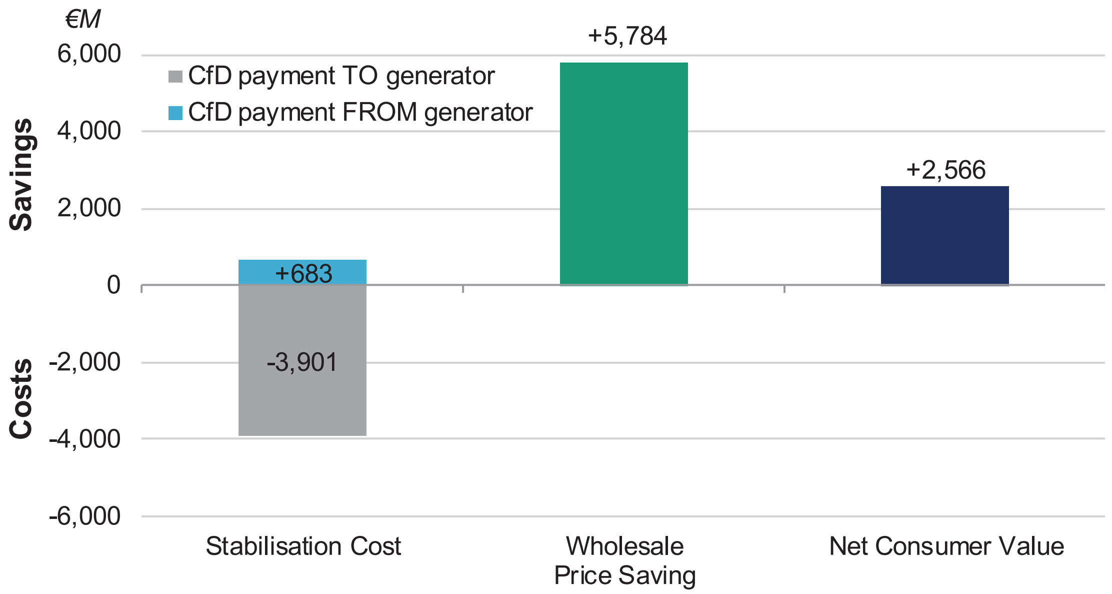
3 All of our analyses in this report are presented in 2017 money terms.

4 This analysis is based on a simplified scenario where all the additional renewables capacity required to achieve 70% renewables penetration enters into CfDs with a strike price of €60/MWh. Given the trajectory of costs reductions and the level of some strike prices seen in the market today, this is likely a conservative approach.

5 Further details of what has and has not been considered in this analysis can be found in Box 1.

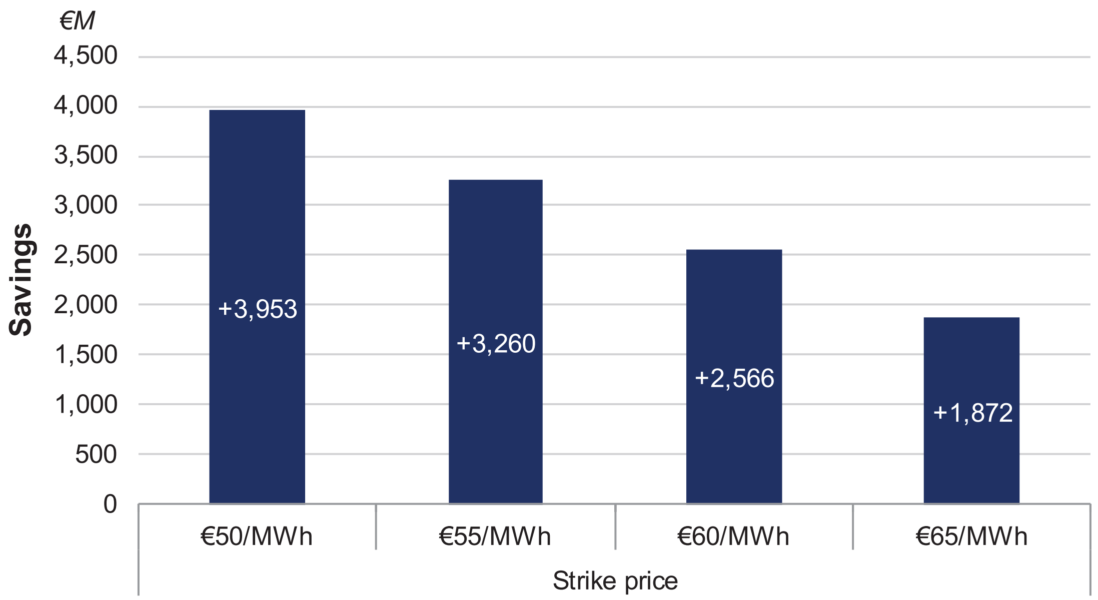
6 BEIS, Contracts for Difference Round 3 Results, 20 September 2019.

Figure 2 – Net Consumer Value estimate assuming a CfD strike price of €60/MWh (€M, real 2017 money)



Note: A discount rate of 6% was used to calculate the net present value.

Figure 3 – Sensitivity of Net Consumer Value to different auction strike prices (€M, real 2017 money)



Note: A discount rate of 6% was used to calculate the net present value.

Box 1 – Assessing the value of CfD supported renewables

With the Renewable Energy Support Scheme (RESS) currently being developed in the Republic of Ireland, IWEA asked Pöyry to assess the value that CfD-supported renewables could bring to consumers in the Irish Single Electricity Market.

We carried out that analysis by using two pathways: one where the Single Electricity market reached 70% renewables penetration by 2030 (the **70x30** pathway); and another where renewables penetration reached 40% by 2020 (as targeted by previous renewable support schemes) and no more renewables capacity was built after 2020 (the **40x20** pathway).

To assess consumer value we balanced the benefits that lower wholesale electricity prices would bring in the **70x30** pathway as compared to the **40x20** pathway (driven by increasing amounts of near-zero marginal cost renewables generation) against the costs to the consumer (e.g. the PSO Levy in the ROI) of supporting these additional renewables. This results in a 'high-level' assessment of the net value that CfD-supported renewables could bring to consumers. We have not included any potential costs related to grid reinforcement or other system costs that may be required to operate a system capable of handling renewables penetration of 70% as these were previously identified in IWEA's 70 by 30 report from October 2018.

Our work relies heavily on IWEA's 70 by 30 report for fuel and carbon price assumptions for the period to 2030. For 2030-40, gas and carbon projections are derived from National Grid's Base case in the 2018 FES. Oil / coal prices in 2030-40 are assumed to be flat in real terms. Demand projections are derived from data published by EirGrid in the Tomorrow's Energy Scenarios 2017 and the All-Island Generation Capacity Statement 2018-28.

Uncertainty for the corporate PPA market

Whilst CfD-supported renewables would appear to represent clear value to consumers in the SEM, the picture is less clear for corporates seeking to enter into CfD-like corporate power purchase agreements (CPPAs) with renewables generators.

With high wholesale prices, CPPAs can offer an attractive package of green attributes and fixed prices at a strike price below the wholesale price. However, in a world of 70% renewables and depressed wholesale prices, the correspondingly lower fixed price that a corporate might look to secure may not be viable for many renewable generators. This may be a headwind for the CPPA market, making the government target of 15% renewables from CPPAs more difficult to achieve.

However, given our analysis suggests there would be a benefit to all consumers if renewables penetration were to reach 70% and CPPAs can provide some of that benefit, there are clear reasons for the development of incentives that might encourage corporates to directly contract with renewables generators.

At this time, it is not clear what the most suitable policies would be for Ireland, but some examples include:

- financial incentives (e.g. tax incentive schemes) for corporates that enter into CPPAs;
- a Norwegian-style[7] energy purchase guarantee scheme where corporates could apply to a state-backed entity that would function as an offtaker of last resort in the event the corporate could not fulfil the terms of the PPA (and in so doing address long-term counterparty-risks); or
- placing obligations on demand customers to purchase electricity contracted under CPPAs.

Further analysis is required to establish the policies most suitable for Ireland, which is part of the work underway in Action 29 of the Climate Action Plan[8].

Conclusions

This analysis shows that if the increase from 40% renewables in 2020 to 70% renewables in 2030 is procured from CfD-supported renewables (e.g. RESS) at an average strike price of €60/MWh, there would be a net saving to the electricity consumer, under the commodity price assumptions used in this analysis of approximately €2.5 billion. For Irish policy makers, contracting renewables at low strike prices under the RESS would appear to be a low-regrets option.

The analysis also shows that the benefit to the electricity consumer largely arises from the lower wholesale prices that result from higher levels of near-zero marginal cost renewables. This significantly outweighs the cost of supporting renewables in the range of strike prices presented in this report.

Although lower wholesale prices benefit all electricity consumers, they could make the economics of CPPAs more challenging unless corporates attach a premium for cost certainty or demonstrating green credentials for their shareholders. If the Irish Government wishes to achieve its ambition of c.15% electricity demand being sourced through CPPAs, it will likely need new policies to facilitate this market.

Achieving 15% renewables by CPPAs would materially reduce wholesale prices to the benefit of all consumers, even though the cost and risk is borne only by the corporate sector. Consequently, there is an economic case for policies to share some of this benefit back to corporates.

7 GIEK, Power purchase guarantee, accessed 16 October 2019.

8 DCCAE, Climate Action Plan 2019, 17 June 2019.

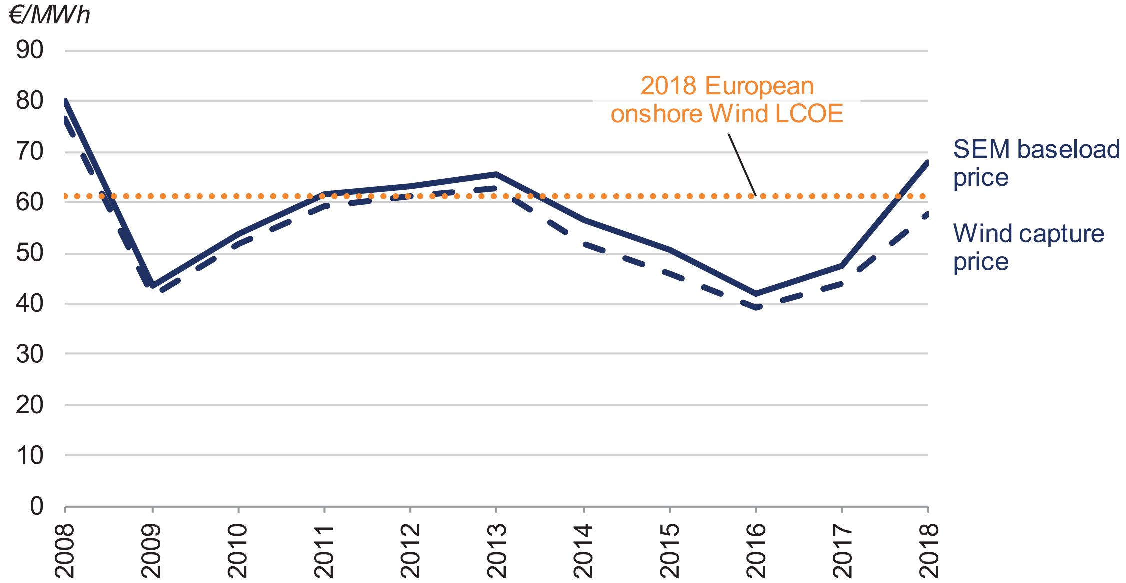
1. BACKGROUND

1.1 Introduction

1.1.1 *Renewables represent increasingly good value*

Renewable electricity generation technologies have never offered better value to consumers following years of cost reductions in the supply chain. For example, in 2018, the International Renewable Energy Agency (IRENA) estimated the levelised cost of electricity (LCOE) from onshore wind in Europe at €61/MWh[9]. These levels are now well within the historical range of wholesale electricity prices seen in the Single Electricity Market (SEM) covering the island of Ireland (Figure 4).

Figure 4 – Historical average wholesale electricity prices in the SEM (€/MWh, nominal money)



Note: The baseload price gives equal weight to all hours in a year and reflects the System Marginal Price in 2008 to September 2018 and the Day Ahead price from October 2018 onwards; the wind capture price weights each hour by the amount of wind generation available that hour.

Source: Wholesale prices – SEMO; wind capture prices – SEMO and EirGrid; onshore wind LCOE – IRENA.

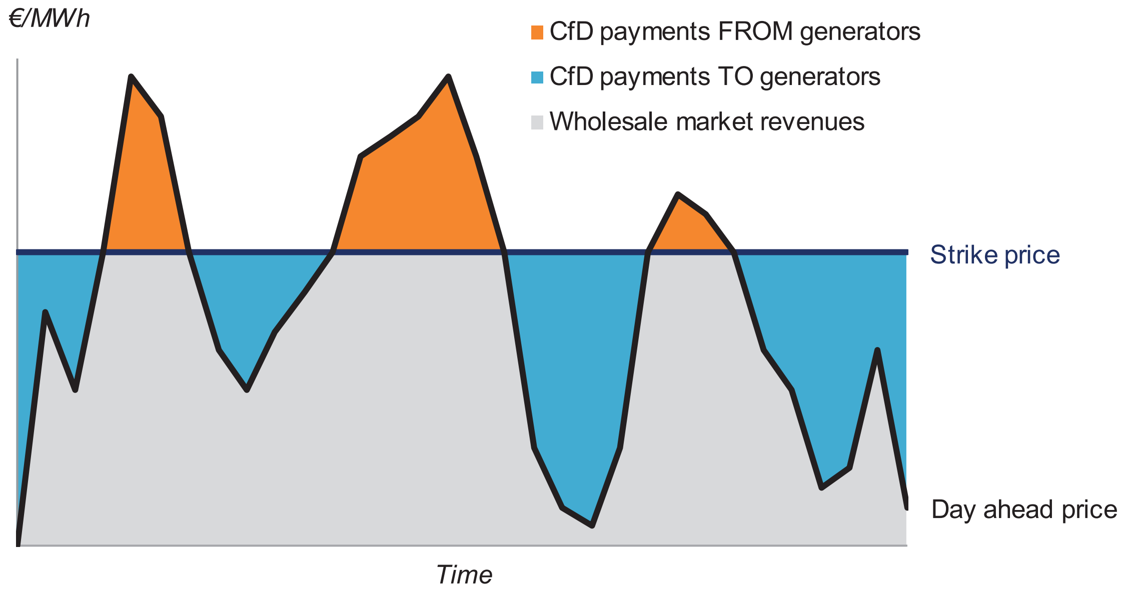
1.1.2 *2-way Contracts-for-Difference are becoming more common*

Contracts for Difference (CfD) and specifically 2-way CfDs are being adopted in many nations across Europe as the main structure for supporting new capacity from large-scale renewable electricity generation technologies. Typically these take the form of government backed contracts, although they can also be found in some (i.e. financial) corporate power purchase agreements (CPPAs).

9 IRENA, Renewable Power Generation Costs in 2018, May 2019.

The new Renewable Energy Support Scheme (RESS) in the Republic of Ireland (ROI) is one such scheme. It is intended that all generators successfully clearing in the RESS auctions will ultimately receive the auction clearing price or their bid price[10] (i.e. the Strike Price), with generators making and receiving payments based on how the Strike Price compares to a market reference price (expected to be the Day-Ahead price) during times of generation. When the Day-Ahead price is lower than the Strike Price, generators will receive a payment from the PSO Levy; when the Day-Ahead price is higher than the Strike Price, generators will make a payment into the PSO Levy. This is shown graphically in Figure 5.

Figure 5 – Financial structure of a 2-way CfD



1.2 Assessing the value of CfD supported renewables

With the RESS currently being developed, Pöyry has been asked by the Irish Wind Energy Association (IWEA) to assess at a high-level the value that CfD-supported renewables could bring to Irish consumers.

Conceptually, our assessment of Consumer Value trades off:

1. the benefits that lower wholesale electricity prices (driven by increasing amounts of zero marginal cost renewables generation) offer consumers; versus
2. the costs to the consumer (e.g. the PSO Levy) of supporting these additional renewables.

We have not included any assessment of grid reinforcement or other system costs (e.g. DS3) that may be required to operate a system capable of handling renewables penetration of 70% as these were previously analysed in IWEA's 70 by 30 report.

10 The auction design can be either 'Pay-as-Clear' where all participants receive the same clearing price or 'Pay-as-Bid' where each participant receives their bid price.

To answer (1), we have simulated two possible directions that the Irish electricity market could take:

- a '**70x30**' pathway that assumes renewables penetration in the SEM reaches 70% by 2030 (i.e. 70% of electricity demand is satisfied by renewable generation); and
- a '**40x20**' pathway that assumes renewables capacity flat lines from 2020 with future demand growth satisfied by increasing amounts of new build thermal capacity.

By using the **40x20** pathway as a counter-factual, we can assess the downward impact that additional CfD-supported generation has on electricity prices. We can then use the **70x30** pathway to establish how much the cost of stabilising[11] CfD-supported renewables might offset the benefits of lower wholesale prices. Ultimately, this allows for a high-level estimate of the net value that CfD-supported renewables could bring to consumers.

1.3 Structure of this report

In the rest of this report, we:

- outline our methodology in Chapter 2;
- present the key findings of our analysis in Chapter 3; and
- discuss the value of that CfD-supported renewables for corporates in Chapter 4.

1.4 Conventions

The following conventions are observed throughout this report:

- all monetary values quoted in this report are in euro in real 2017 prices, unless otherwise stated;
- annual data relates to calendar years running from 1 January to 31 December, unless otherwise identified; and
- plant efficiencies throughout this report are defined at the Higher Heating Value (HHV) basis. Fuel prices are similarly quoted on a gross (HHV) basis.

1.5 Sources

Unless otherwise attributed the source for all tables, figures and charts is Pöyry Management Consulting.

11 This may take the form of government backed support (e.g. the RESS in the ROI or a currently hypothetical NI support scheme) or consumers paying above market prices for electricity (e.g. corporates striking PPAs at above market prices).

2. METHODOLOGY & ASSUMPTIONS

2.1 Definition of Consumer Value

As described in Chapter 0, our approach to establishing the value of RESS-supported renewables to consumers relies on estimating:

1. the 'Wholesale Price Saving' (i.e. how much electricity prices fall in a world with a significant amount of renewables capacity vs. a world with much less renewables capacity); and
2. the cost of stabilising the additional renewables that drive wholesale prices lower, what we term the 'Stabilisation Cost'.

2.1.1 Wholesale Price Saving

Because wind and solar have very low variable generation costs, in a system where electricity prices are fundamentally set by the variable cost of generation, higher levels of wind and solar capacity will typically result in lower wholesale electricity prices. To quantify how much electricity prices might fall and what benefits this could bring to the consumer, we have modelled two alternative pathways based on commodity costs provided by IWEA/public sources and which differ only in their renewables ambition:

- the '**70x30**' pathway, which assumes 70% renewables penetration across the SEM by 2030, with additional renewables supported by some form of CfD; and
- a '**40x20**' pathway, which assumes renewables capacity does not change post 2020.

The Wholesale Price Saving has been calculated as the difference in price in each hour multiplied by the amount of demand in each hour.

2.1.2 Stabilisation Cost

Renewables capacity built in the SEM after 2020 will likely require some form of revenue stabilisation mechanism in order to mitigate risks to levels acceptable for large scale investment. In the ROI, this will primarily affect the size of the PSO Levy, but to the extent that CPPAs are struck at levels that result in some additional renewables capacity, corporate Ireland would also be providing a share of this support.

In this case, the Stabilisation Cost has been calculated as the difference between the wholesale price and a range of putative CfD strike prices multiplied by the volume of renewables generation supported by CfDs in each hour.

2.1.3 Net Consumer Value

By balancing the Wholesale Price Saving and the Stabilisation Cost against each other, we can establish a reasonable high-level proxy for 'Net Consumer Value'. This can then be assessed over time to estimate the value of CfD-supported renewables. In this case, we have considered the period from 2025 to 2040. All of the financial results are presented in real 2017 money unless otherwise stated.

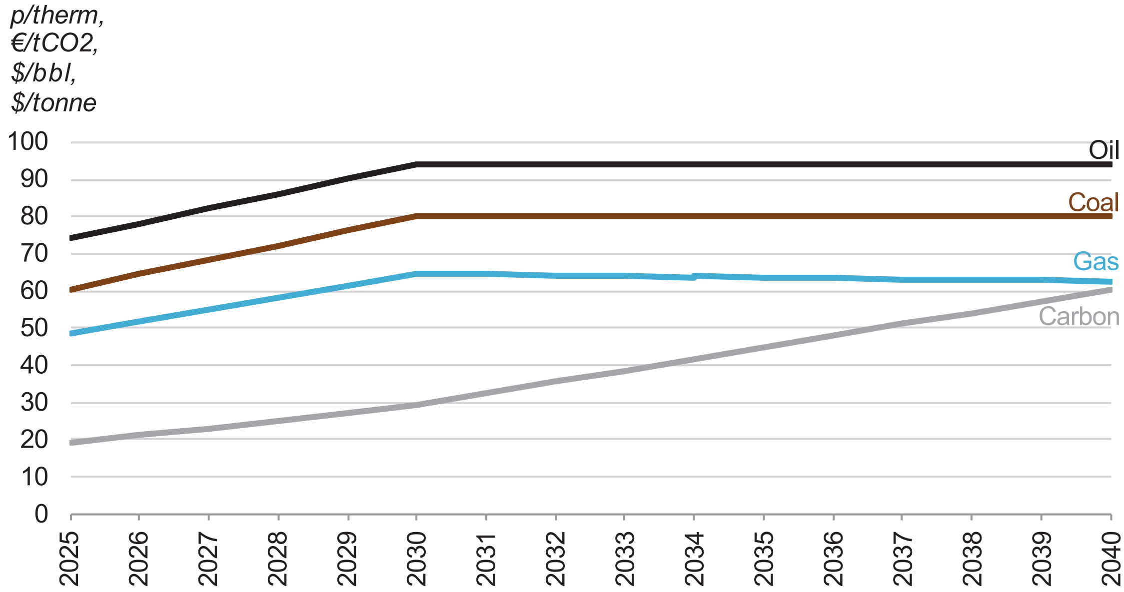
2.2 Key inputs

Apart from installed capacities, all assumptions were the same in both pathways.

2.2.1 Fuel and carbon prices

Fuel and carbon prices were based on IWEA's *70 by 30* report[12] for the period to 2030 and derived from independent sources[13] for the period 2030-40. A summary of the fuel and carbon price inputs used can be seen in Figure 6.

Figure 6 – Fuel and carbon price assumptions
(Gas (NBP) – p/therm, Carbon (EU ETS) – €/tCO_2, Oil (Brent) – $/bbl, Coal (ARA CIF) – $/tonne, all real 2017 money)



2.2.2 Demand

Demand projections were derived from forward looking data in EirGrid's Tomorrow's Energy Scenarios 2017[14] and EirGrid's Generation Capacity Statement 2018-27[15] (Figure 7).

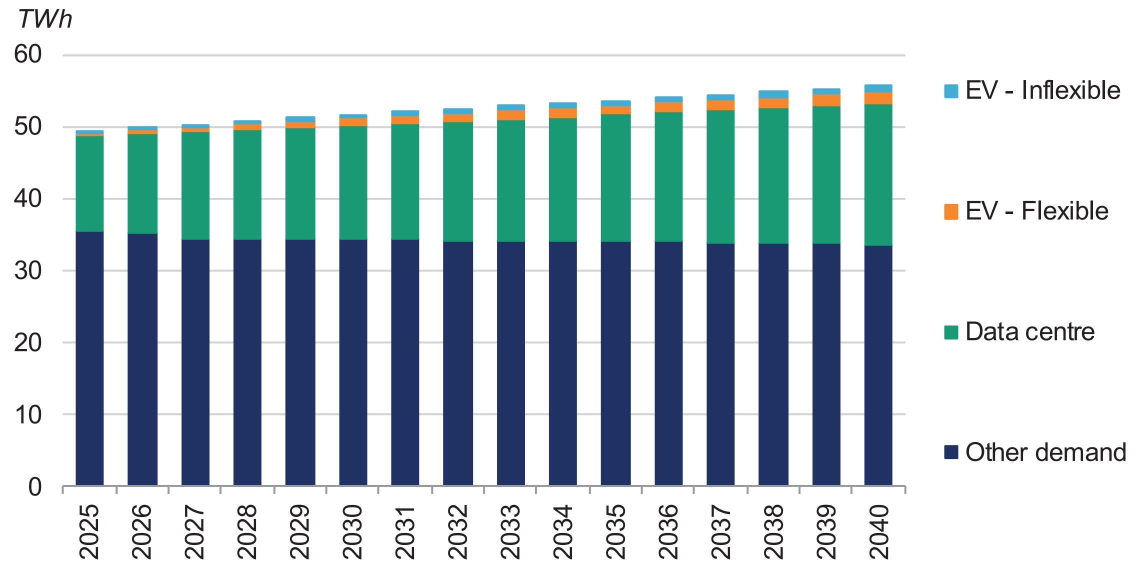
12 IWEA, 70 by 30: A 70% Renewable Electricity Vision for Ireland in 2030, October 2018.

13 The National Grid Future Energy Scenarios Base Case was used for natural gas and carbon prices; oil and coal prices were assumed to be flat.

14 EirGrid, Tomorrow's Energy Scenarios 2017, July 2017.

15 EirGrid, All-Island Generation Capacity Statement 2018-28, 22 October 2018.

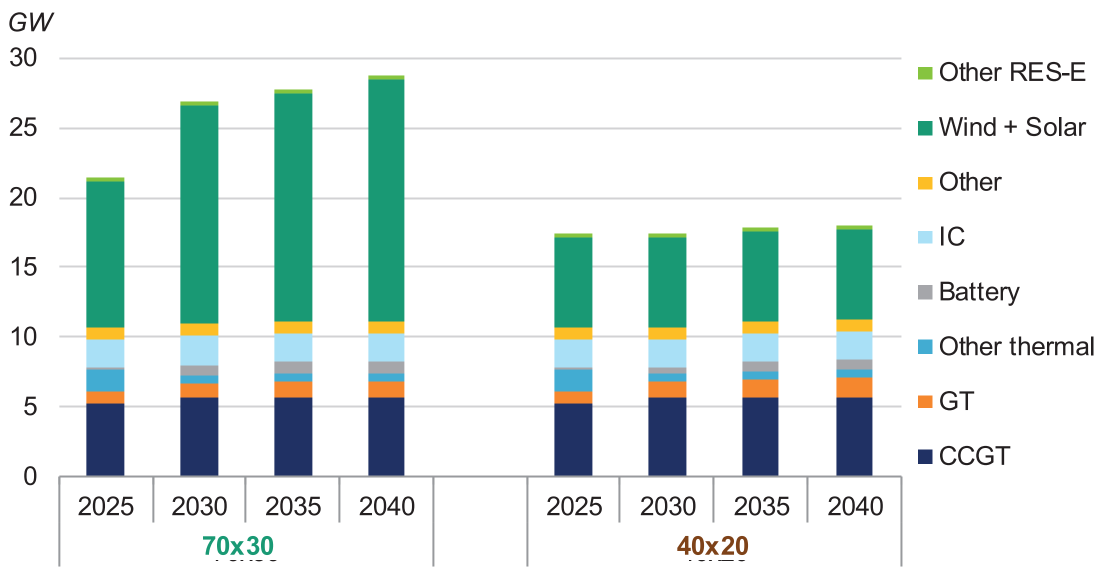
Figure 7 – Annual demand assumptions for the all island Single Electricity Market (TWh)



2.2.3 Capacity mix

The capacity mix and specifically the development of new renewable capacity is the primary difference between the **70x30** and **40x20** pathways. In the **70x30** pathway, renewables capacity increases to 17.7GW by 2040 compared to only 6.8GW in the **40x20** pathway (Figure 8). Thermal capacity is largely similar in the two pathways, due to the additional renewables capacity in the **70x30** pathway providing limited incremental generation capacity at times of peak demand. Consequently, a similar amount of thermal generation is required to provide system security. The key difference is that in the 70x30 thermal generators are generating far less electricity.

Figure 8 – SEM capacity mix in the 70x30 and 40x20 pathways (GW)



3. NET CONSUMER VALUE

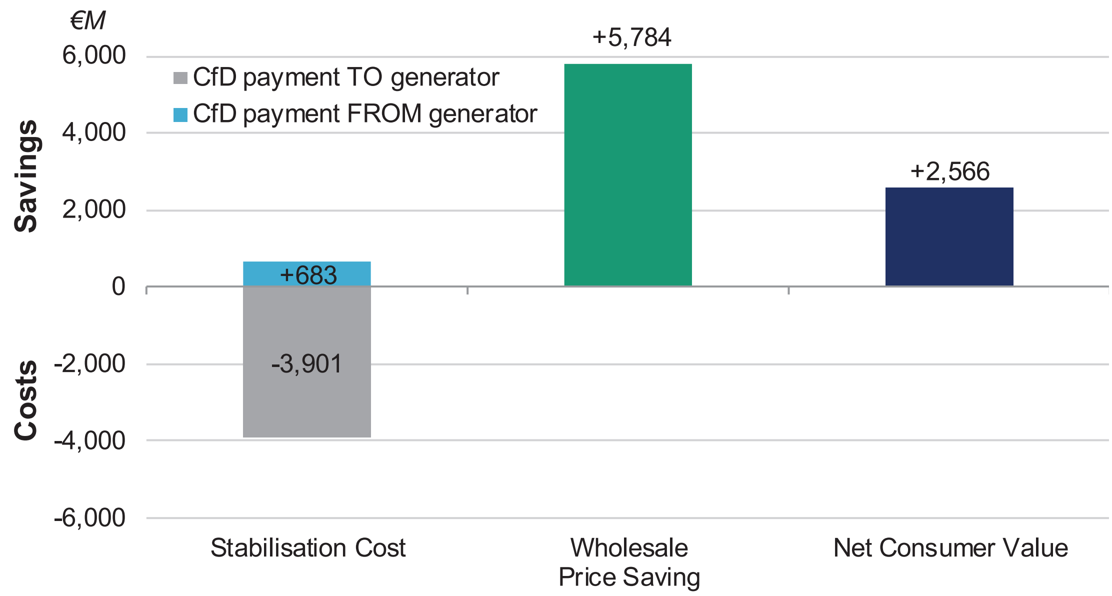
3.1 Net Consumer Value

Our analysis suggests that if CfD strike prices come in at €60/MWh[16] over the fifteen year period from 2025 to 2040[17], consumers in both Northern Ireland (NI) and the Republic of Ireland (ROI) could benefit by around €2.5B on the basis of the assumptions behind the two pathways modelled. This is outlined in Figure 9.

CfD-supported generators would receive around €4B in payments whilst also repaying (i.e. reducing their net Stabilisation Cost) almost €700M in hours when wholesale electricity prices were high.

This results in a net Stabilisation Cost of around €3.2B if strike prices were €60/MWh. However, reduced wholesale electricity prices more than offset this cost, benefitting consumers by around €5.8B (real 2017 money) between 2025 and 2040.

Figure 9 – Net Consumer Value estimate assuming a CfD strike price of €60/MWh (€M, real 2017 money)



Note: A discount rate of 6% was used to calculate the net present value.

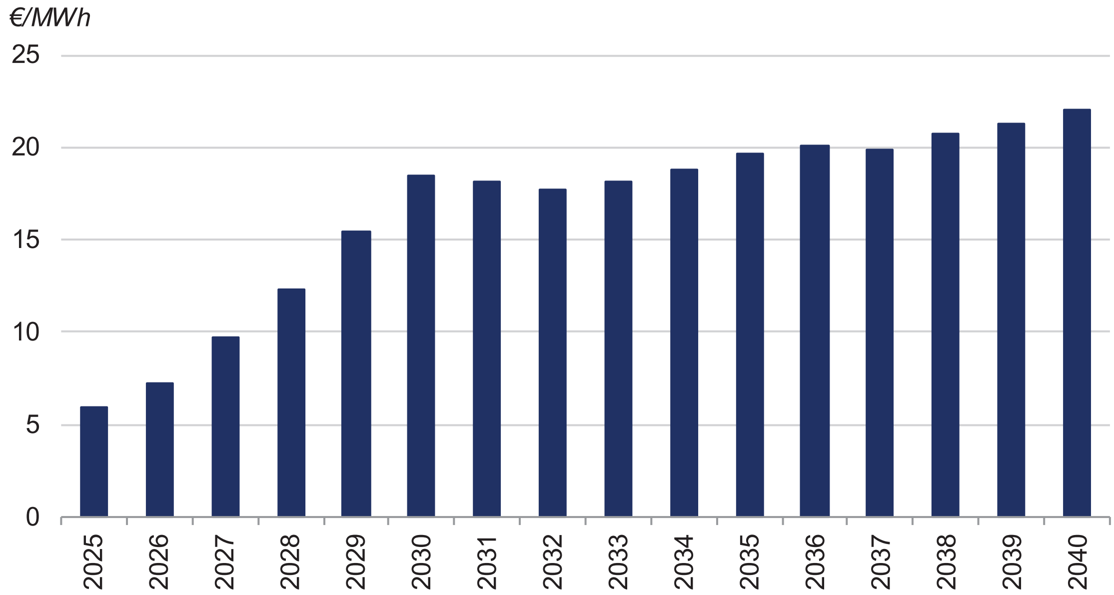
16 All of our analyses in this report are presented in 2017 money terms.

17 This analysis is based on a simplistic scenario where all the additional renewables capacity required to achieve 70% renewables penetration enters into CfDs with a strike price of €60/MWh. Given the trajectory of costs reductions and the level of some strike prices seen in the market today, this is likely a conservative approach.

3.2 Wholesale Price Saving

The saving on wholesale prices of increasing renewables penetration is significant, with a c.€20/MWh difference in wholesale electricity price projections[18] from 2030 (Figure 10). With increasing amounts of renewable capacity on the system, the number of hours in a year where prices are set by low variable cost renewables increases. This in turn results in annual average electricity prices falling. The Wholesale Price Saving in Figure 9 represents the sum total[19] over the period 2025-40 in present value terms[20].

Figure 10 – Annual impact on wholesale prices (€/MWh, real 2017 money)



Note: Figures above show the difference in annual average demand-weighted wholesale electricity prices calculated as **40x20** pathway minus **70x30** pathway. Positive values thus represent a benefit for consumers.

3.3 Sensitivity analysis

The sensitivity of Stabilisation Costs to different auction strike prices is shown in Figure 11. The upper end of the range reflects LCOEs typically seen for onshore wind in Europe currently. The lower end of the range is closer to (but not as low as) the prices at which offshore wind auctions in Europe have recently been clearing. We believe this represents a reasonable range of outcomes for the likely cost of CfDs in Ireland.

The sensitivity of Net Consumer Value to different auction strike prices is shown in Figure 12. Our analysis suggests that even at current onshore wind costs, CfD-supported renewables are likely to benefit consumers by a little under €2B (real 2017 money). If

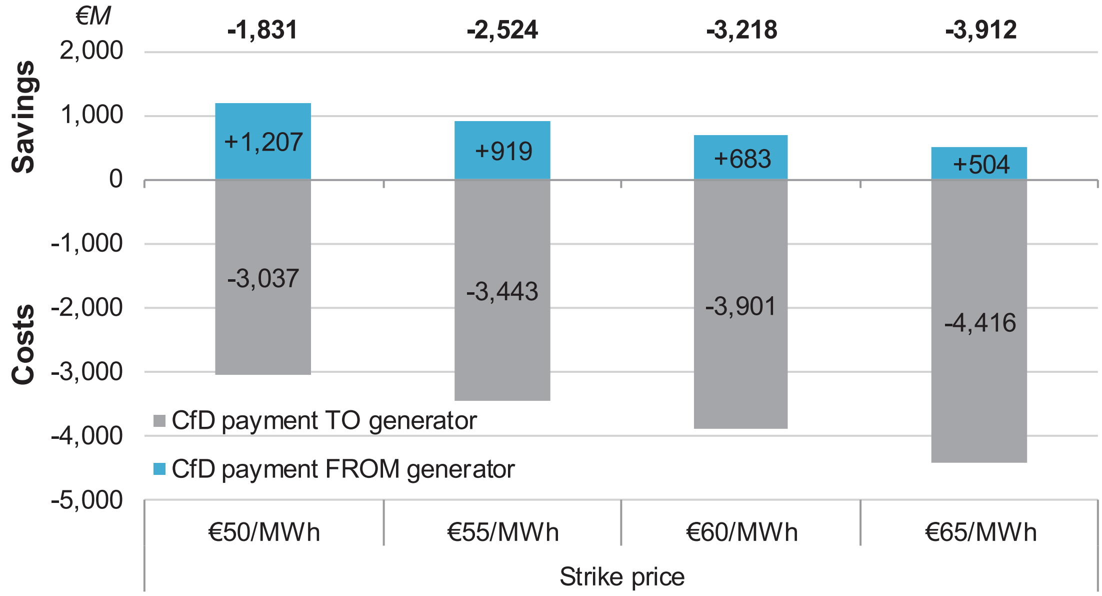
18 These are defined as demand-weighted annual average electricity prices; i.e. hourly wholesale electricity prices are weighted in proportion to electricity demand in each hour.

19 I.e. the difference in hourly prices multiplied by the demand in each hour summed over the period 2025-40.

20 We have assumed a discount rate of 6%.

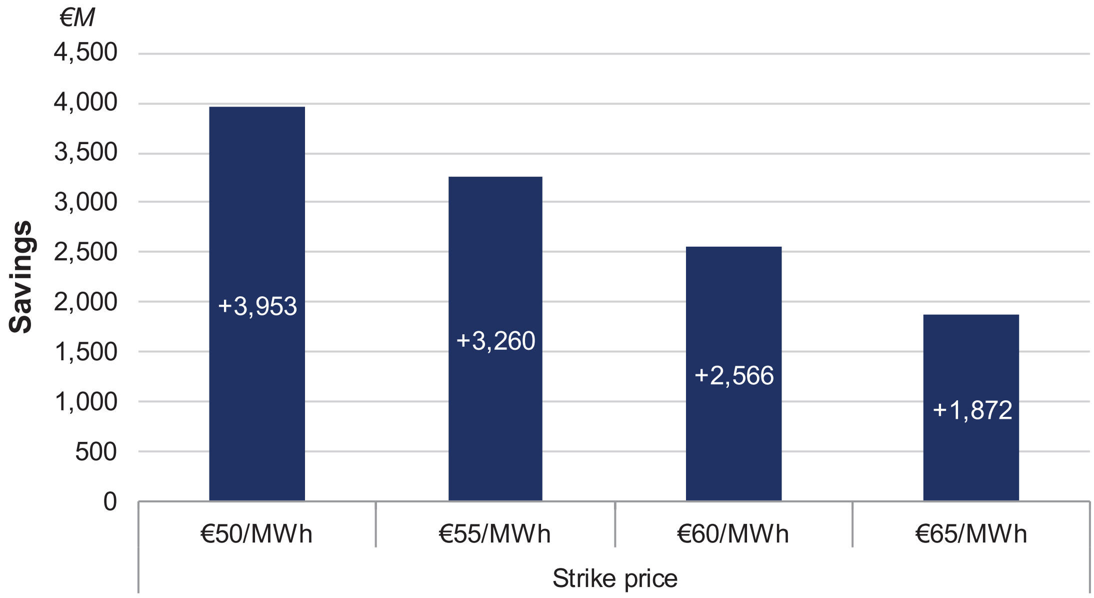
renewables costs continue to fall significantly (i.e. strike prices are €50/MWh), the benefits could reach €4B (real 2017 money).

Figure 11 – Sensitivity of Stabilisation Cost to different CfD strike prices (€M, real 2017 money)



Note: A discount rate of 6% was used to calculate the net present value.

Figure 12 – Sensitivity of Net Consumer Value to different auction strike prices (€M, real 2017 money)



Note: A discount rate of 6% was used to calculate the net present value.

4. THE VALUE OF CFDS TO CORPORATES

So far, we have focussed on the value of CfD-supported renewables to the consumer, making little distinction between Government-backed RESS contracts and CfD-like corporate power purchasing agreements (CPPAs).

Now we turn our attention to CPPAs, as their value from the perspective of a corporate entering into such a contract is somewhat different to that of a RESS contract.

When a corporate entity is considering how it procures power, the primary consideration is expected to be the price the corporate must pay for its electricity. Wider benefits including the benefit to consumers of falling wholesale prices are of secondary importance.

More specifically, in a world of high renewables penetration and depressed wholesale prices, the fixed price that a corporate might look to secure may not be viable for many renewables generators seeking some form of price-risk mitigating offtake agreement.

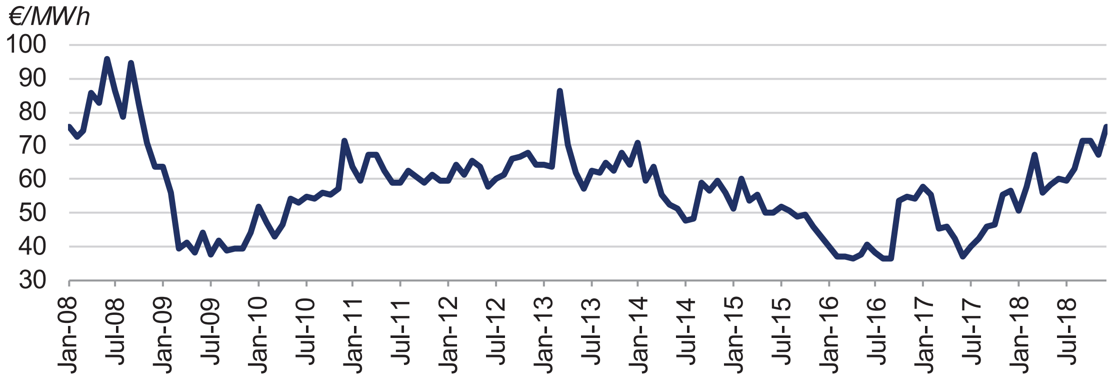
Whilst price may be the primary consideration in a corporate's decision-making process, it is not necessarily the only consideration. Managing risk will play a role and securing a fixed price may well have advantages from a budgeting and planning perspective. This is particularly true if one expects significant increases in the cost of carbon and the upward effect that would have on wholesale power prices (in the majority of hours when thermal plant is setting the price).

There is also a trend for shareholders to require corporates to demonstrate their green credentials and a well-structured CPPA that delivers new renewable capacity is a good way to demonstrate such intentions.

4.1 Benefits of hedging

One of the main benefits of a CPPA with a fixed strike price is the certainty it can bring with respect to electricity prices. In the SEM, annual average baseload electricity prices have ranged between €40/MWh and €80/MWh over the last decade (Figure 13) driven by considerable commodity price volatility. A CPPA can provide a corporate with a fixed electricity price into the future rather than being exposed to this volatility.

Figure 13 – Annual average baseload electricity prices in the SEM (€/MWh, nominal money)

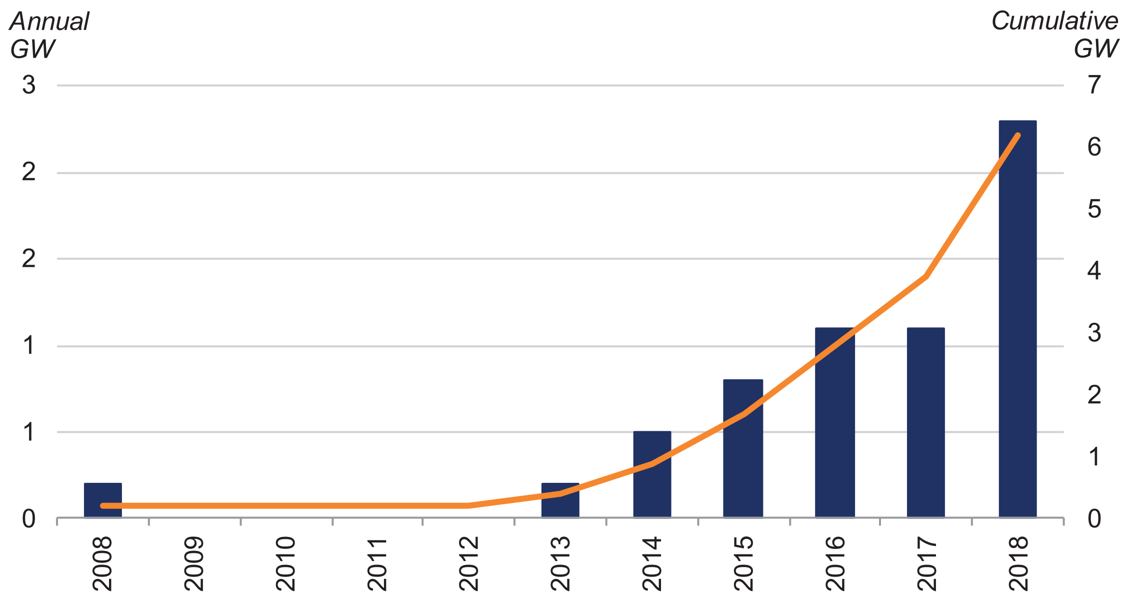


4.2 The value of green energy

Sustainability and climate objectives appear to have gained significant traction in the eyes of shareholders. Unsurprisingly, the amount of renewable energy capacity that corporates have been contracting directly has also been increasing, partly in response to this pressure.

In the SEM, two CPPAs have been announced in 2019 covering 115MW of onshore wind capacity with Amazon[21,22], a company that places strong emphasis on sustainability and renewable energy sourcing[23].

Figure 14 – Uptake of clean energy corporate PPAs in the EMEA region (GW)



Source: BloombergNEF.

4.3 Sharing the savings

In a world of high renewable penetration, there can be significant depression of wholesale prices. This can act as a disincentive to corporates to contract directly with renewables generators under a CPPA because generators are likely to require a premium to market prices. Therefore, unless corporates place a significant value premium on demonstrating green credentials to shareholders or hedging against increasing wholesale prices, achieving the target of 15% of renewables from private investment envisaged under the Climate Action Plan[24] could be challenging.

21 Amazon Web Services, Amazon Announces New Renewable Energy Project in Ireland to Support AWS Global Infrastructure, 8 April 2019.

22 Cork Beo, Amazon to invest in major new wind farm in Cork, 1 August 2019.

23 Amazon, Sustainability, accessed 7 October 2019.

24 DCCAE, Climate Action Plan 2019, 17 June 2019.

Because achieving 15% renewables by CPPAs would materially reduce wholesale prices to the benefit of all consumers despite the costs and risks being borne by the corporate sector, there is some economic justification for policies to share this benefit back to corporates and large energy users.

5. CONCLUSIONS

1. *Consumers stand to benefit*

Building a significant amount of CfD-supported renewables in the SEM could bring significant value to consumers. Specifically, our analysis suggests that if sufficient renewables capacity were built to take renewables penetration to 70% across the SEM and these renewables were supported by CfDs struck at €60/MWh, there could be a net saving to the electricity consumer of c.€2.5B. Although this analysis ignores the costs of ensuring the system could handle such high levels of renewables, nonetheless, stabilising renewables with CfDs appears to be a low regrets option for Irish policy makers.

2. *Benefit mainly arises from lower wholesale prices*

The benefits described above largely arise from the lower wholesale prices brought about by having higher levels of near-zero marginal cost renewables. With electricity prices tending to be set by the marginal cost of generation, having more renewables means more hours where the price is set by a technology with costs close to zero. Importantly, this significantly outweighs the cost of supporting these renewables.

3. *Corporates can benefit without having to contract directly*

Lower wholesale prices benefit all electricity consumers, including corporates. This means that corporates can receive the benefits of additional renewables without having to incur the direct and potentially higher costs of contracting directly with a generator via a CPPA (although like residential consumers, the costs of supporting renewables would ultimately be passed on to corporates indirectly via higher electricity bills from their energy supplier). Consequently, the economics of CPPAs may be quite challenging.

4. *There is a strong economic case for new policies to stimulate the CPPA market.*

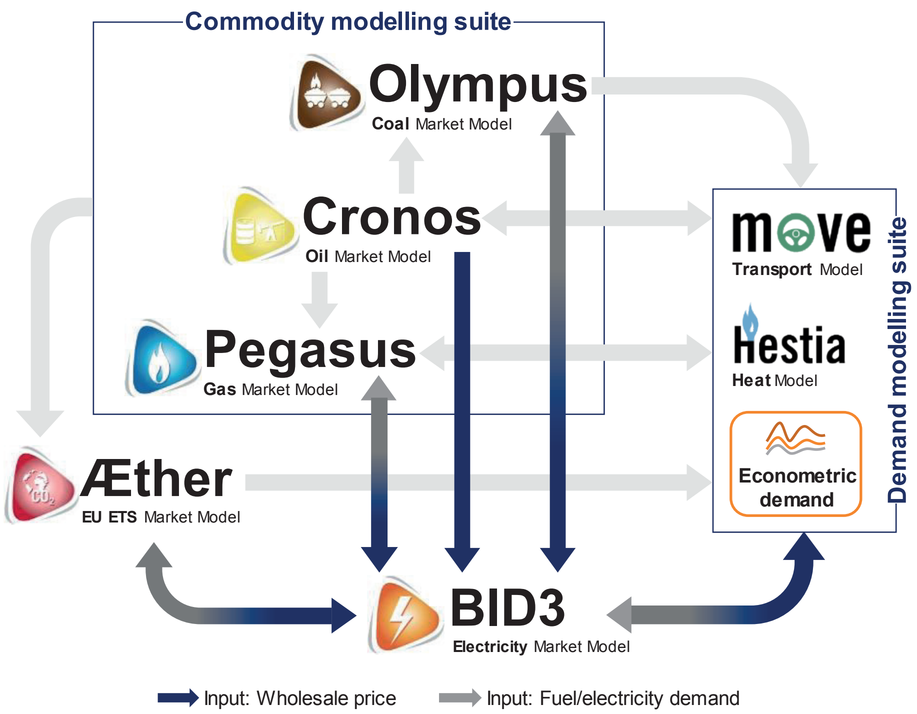
If the Irish Government wishes to achieve its target of 15% electricity demand being sourced through CPPAs, it may need new policies to facilitate this market. Achieving 15% renewables penetration from CPPAs would materially reduce wholesale prices to the benefit of all consumers even though the cost and risk is only borne by the corporate sector. Consequently, there is an economic case for policies to share some (or all) of this benefit back to corporates.

ANNEX A – BID3 ELECTRICITY MARKET MODEL

A.1 What is the role of BID3 in Pöyry's energy system?

BID3 provides a simulation of all the major power market metrics on an hourly basis – electricity prices, dispatch of power plants and flows across interconnectors. It works in an interactive manner with our commodity market, heat and transport models, receiving the commodity prices, as well as the demand for heat and transport from them; and feeding back the power demand for the commodities and the electricity prices to these models (Figure 15).

Figure 15 – BID3's place in Pöyry's energy system

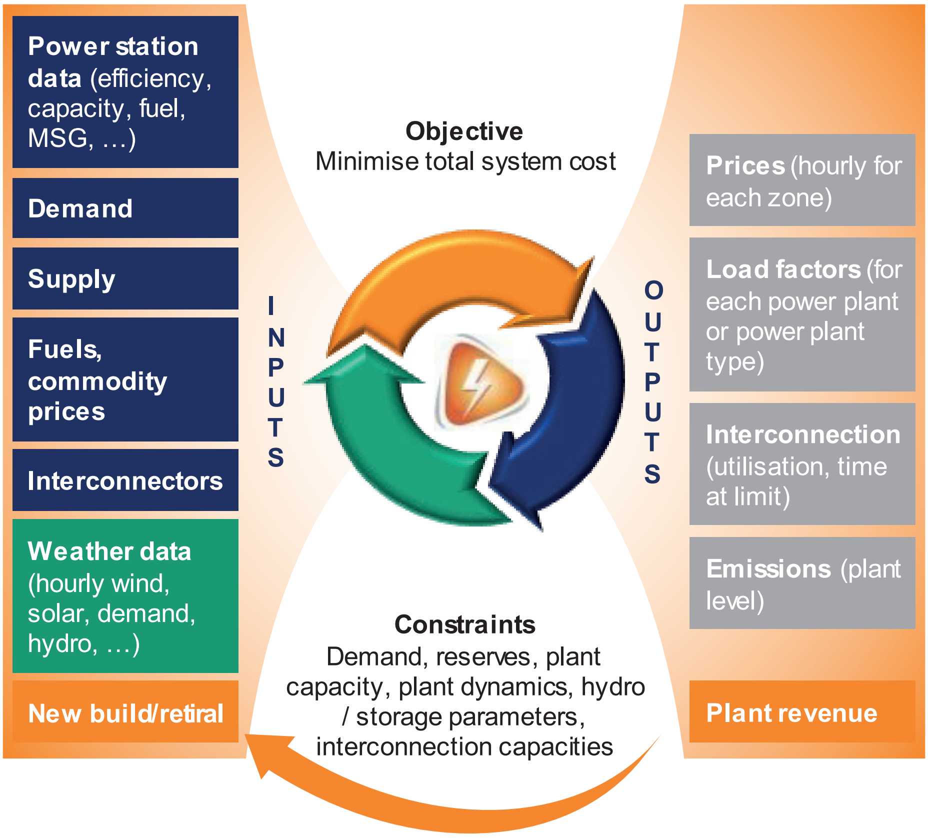


A.2 How does BID3 work?

BID3 is an economic dispatch model based around optimisation. It simulates the hourly generation of all power stations on the system, taking into account fuel prices and operational constraints such as the cost of starting a plant (Figure 16). It accurately models renewable sources of generation such as hydro, reflecting the option value of water, and intermittent sources of generation, such as wind and solar using detailed and consistent historical wind speed and solar radiation.

The result of this optimisation is an hourly dispatch schedule for all power plants and interconnectors on the system. At the high level, this is equivalent to modelling the market by the intersection between a supply curve and a demand curve for each hour.

Figure 16 – BID3 overview



A.2.1 Demand

There are several tranches of annual electricity demand including:

- electrified transport (largely electric road vehicles (cars, trucks, buses) and rail transport) which comes from the transport sector model, Move;
- electrified heat (predominantly space heating) which comes from the heat sector model Hestia; and
- residual 'economically sensitive' demand (predominantly driven by GDP growth and assumptions around energy efficiency).

Annual demand is disaggregated into hourly values via a series of demand profiles that take into account historic weather patterns and demand flexibility (in the case of EVs and heating).

A.2.2 Supply

There are several factors influencing the supply curve, including (amongst others):

- the existing fleet of thermal assets;
- intermittent renewables;
- hydro;
- interconnection;
- the evolution technology costs; and
- fuel prices.

Existing thermal assets

We maintain an extensive database of all thermal assets across Europe, with information on a range of parameters including (amongst others): fuel types; nameplate capacity; efficiency; co-firing status; start-up costs; and minimum stable generation (MSG).

Intermittent renewables

For intermittent renewables, we estimate hourly load factor profiles on a regional basis (this can be a whole country, a price zone or local regions within a country) and apply these to our projections of installed capacity.

Taking onshore wind as an example (a similar process is used for solar PV), the regional hourly load factor profile is based on: the locations of known wind farms within the region; hourly average wind speeds at each wind farm's location; the hub height of turbines at each wind farm; appropriate aggregate power curves for each wind farm; and the capacity of each wind farm.

New capacity can have different load factors to existing capacity typically as a result of improvements in turbine technology and higher hub heights.

Importantly, we use consistent historical weather and demand profiles (i.e. both from the same historical year) which means we capture any correlations between weather and demand, and can also sample a variety of conditions – for example a particularly windy year, or a cold, high demand, low wind period.

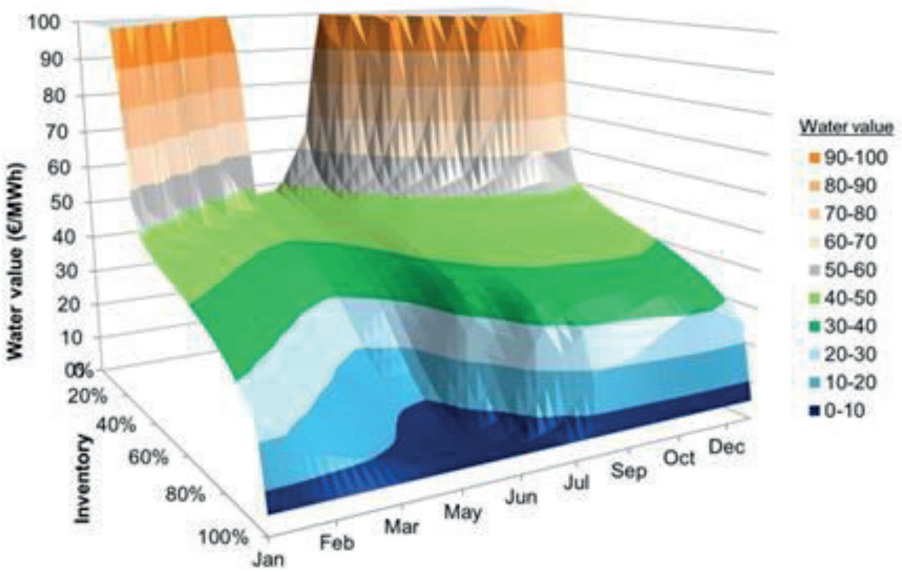
Hydro

For reservoir hydro, the decision regarding how much water to dispatch for power generation and how much to store in the reservoir for later is associated with a high degree of uncertainty. Consequently, BID3 allows reservoir hydro plants to be dispatched using either:

1. Perfect foresight methodology, where each reservoir has a one year of foresight of its natural inflow and the seasonal power price level, and is able to fix the seasonality of its operation in an optimal way. This is used for the thermal-dominated markets in Europe.
2. Water value method, where the option value of stored water is calculated using Stochastic Dynamic Programming. This results in a water value curve where the option value of a stored MWh is a function of the filling level of the reservoir, the filling

level of competing reservoirs, and the time of year. This is used for the Nordics. Figure 17 shows an example water value curve.

Figure 17 – Water value curve



Interconnection

We model both existing and new interconnection between zones. Interconnectors are assumed to be optimally utilised, i.e. equivalent to a market coupling arrangement.

Technology costs

We model the evolution of costs (capex and opex) for all generation technology types based on: observed data; discussions with our network of industry contacts; and learning rate analyses for battery storage and intermittent renewables.

Fuel prices

Fuel prices are a key determinant of the short-run marginal cost of generation. BID3 takes underlying commodity prices from our suite of commodity models and converts these to input fuel prices using an econometric analysis looking at the historical relationship between underlying commodity prices and input fuel prices.

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