Department for
Business, Energy
& Industrial Strategy

BEIS 2017 FOSSIL FUEL PRICE ASSUMPTIONS

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BEIS 2017 FOSSIL FUEL PRICE ASSUMPTIONS

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Introduction

1. This note presents an update to BEIS's long-term price assumptions for oil, gas and coal. These are assumptions for the wholesale fossil fuel prices that are relevant for the UK economy and which are set in international markets. For the oil price, which is set in a global market, this is the 1 month Brent price, which is quoted in US $/barrel. For the gas price, which reflects European gas market conditions, with the European market linked to other regional markets (especially North America and Asia), this is the National Balancing Point (NBP) spot price, which is quoted in pence/therm. For the coal price, this is the ARA CIF price, quoted in US $/tonne, which reflects European coal market conditions, again with regional links.

2. Making assumptions about fossil fuel prices far into the future is – needless to say – very challenging, as they depend on a large number of unknowns (e.g. future economic growth rates across the world, development of new technologies, global climate change policies, technological developments and strategies of resource holders). BEIS produces a set of price assumptions based on available evidence around these fundamentals and their potential development over time so as to yield a plausible range for future prices. These assumptions are required for long-term modelling of the UK energy system and economic appraisal. They are not forecasts of future energy prices.

3. While the BEIS assumptions feed into policy appraisal and modelling work across Whitehall, estimates of public finances are made independently by the Office for Budget Responsibility (OBR) using their own fuel price assumptions. The OBR produces these assumptions for the short and medium term, but not long term. To the extent that the BEIS and OBR assumptions overlap, similar methodologies are used.

4. The price assumptions have been subjected to peer review by a panel of external experts appointed by the former DECC who have impartially scrutinised the analysis used for the fossil fuel price assumptions. The panel's report is published alongside this document[1].

[1] At https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/663090/2017_Expert_Panel_Final_Report.pdf

Methodology and Approach

Overall Methodology and Approach

1. The overall approach for each fuel is :
    - a market based view over the short-term using futures and options[2] prices to aggregate price and volatility expectations from market participants; and
    - a long term fundamentals based view that anchors the long term price at the expected future full economic cost of supply.

2. Over the short term the use of futures/forwards curves is a market based approach for aggregating the information of market participants. The OBR and Bank of England follow the same approach for their short term price assumptions. We recognise that at any point in time futures/forward curves may have embedded risk premia so they are not perfect representations of market expectations. Limited market liquidity may also curb the quality of the price discovery[3].

3. Anchoring the long term price at the expected future full economic cost of production is a transparent and economically sound approach that is consistent with Treasury (Green Book) methodology for policy appraisal. Long term fossil fuel price assumptions are intended to reflect average price levels over a decade or more.

4. In 2016 we commissioned Wood Mackenzie to produce long run supply curves for each fuel including a plausible range of uncertainty (a low and high as well as central view)[4].

5. Part of this year's process included making an assessment of whether the supply curves provided by Wood Mackenzie and their underlying assumptions were still appropriate to use in computing this year's long run price assumptions. Underlying assumptions were analysed and discussed with our expert panel members. A conclusion was reached that there were no fundamental changes in the long term outlook for supply for each fuel, although we have made some specific adjustments to the supply curves which are detailed in the separate fuel chapters.

6. For each fuel we have combined the three updated long term supply outlooks (from Wood Mackenzie) with three demand projections (from three long term scenarios by the International Energy Agency (IEA))[5]. The IEA model three core scenarios for global energy demand, which differ in their assumptions about the evolution of energy-related government policies: the New Policies Scenario; the Current Policies Scenario; and the

[2] For coal data on options prices was not available and historical forecast errors used instead.

[3] For this reason we like the OBR and as advised by the Expert Panel have only used forward prices for the first two years of the assumptions.

[4] At https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/565992/BEIS_WM_Fossil_Fuel_Supply_Curves_Final_Report.pdf

[5] The Coal high price assumption uses EU Energy Trends to 2050 as discussed in paragraph 68.

450 Scenario. The New Policies Scenario is their central scenario and takes into account policies and interventions that have been adopted as of mid-2016 in addition to other relevant declared policy interventions. The Current Policies simply takes into account policies already enacted (as of mid-2016). The 450 Scenario depicts a pathway to the 2°C climate goal that can be achieved by fostering technologies close to being available on a commercial scale. We use the New Policies Scenario for central demand assumptions, Current Policies for high and 450 Scenario for low demand assumptions.

7. Combining high supply with the low demand and low supply with high demand to construct the long term low and high price assumptions for each fuel yields long term price assumptions that span a wide range of possible outcomes. While the long term demand projections and supply outlooks are from different sources, we considered these combinations to be plausible for each fuel.

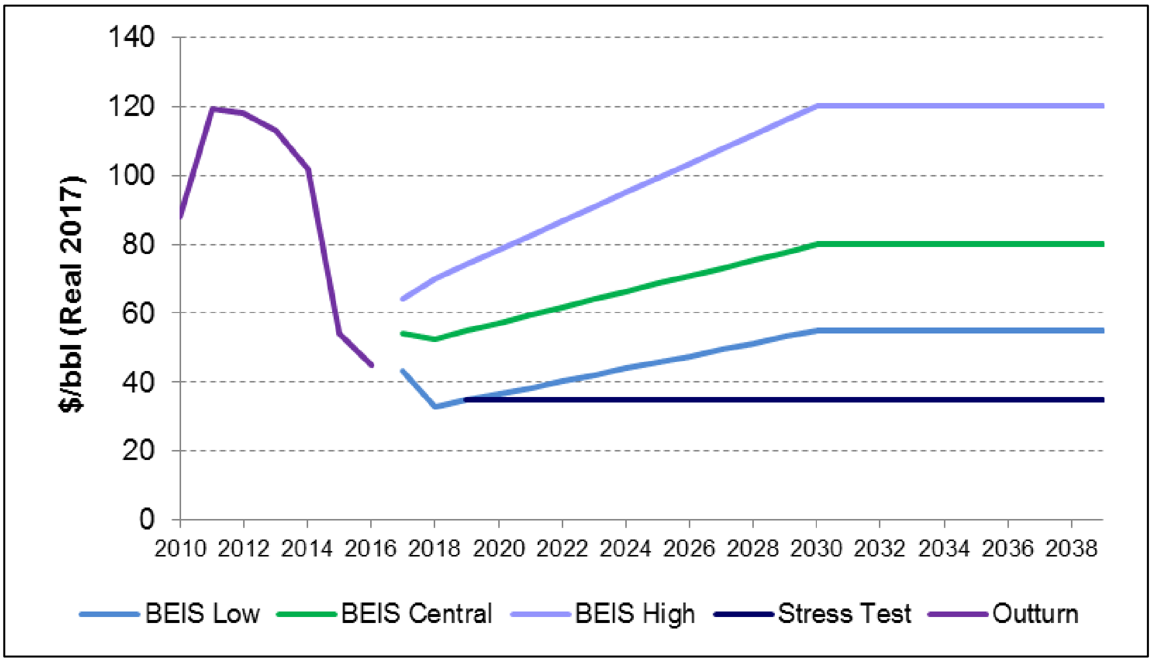
8. The price assumptions for intermediate years are simple linear interpolations. We do not attempt to model detailed dynamics or price cycles. Our primary focus is on a range of long term price levels for fossil fuels.

Oil Price Assumptions

Table 1: 2017 BEIS Oil price assumptions

$/bbl	**2017 BEIS Oil price assumptions**			
Real 2017 prices	**Low**	**Central**	**High**	**Stress Test**
2017	42	54	63	
2018	32	53	68	
2019	34	55	73	35
2020	36	57	77	35
2021	38	59	81	35
2022	40	62	86	35
2023	42	64	90	35
2024	44	66	94	35
2025	45	69	98	35
2026	47	71	103	35
2027	49	73	107	35
2028	51	75	111	35
2029	53	78	116	35
2030	55	80	120	35
2031	55	80	120	35
2032	55	80	120	35
2033	55	80	120	35
2034	55	80	120	35
2035	55	80	120	35

Figure 1: BEIS Oil Price Assumptions



Modelling approach

9. The approach used to create BEIS's oil price assumptions is unchanged from 2016 and combines: (a) futures prices and options data for the short term and (b) evidence on the long run (2030) costs of oil production and estimates of long run oil demand to arrive at a long run equilibrium price. For the purposes of creating the oil price assumptions, BEIS considers demand and supply of total oil liquids (which includes crude oil, Natural Gas Liquids (NGLs), and biofuels).

10. The reason for using futures prices over the short term (2017-2018) is that, as frequently traded contracts, they contain all current information available to the market and so provide a measure of market expectations of the path of prices. Beyond this horizon, liquidity is lower and may not offer the same opportunity for price discovery. On this basis we interpolate between 2018 and our long run (2030) anchor to generate price assumptions for the intermediate years.

11. BEIS assumptions are intended to capture a range of plausible oil market dynamics through periods of relative looseness and tightness, but do not attempt to model price cycles. The table below summarises the approach, which is explained in more detail in the following paragraphs. All data are in real 2017 US Dollars. Long run values are rounded to multiples of US$5[6].

Table 2: Summary of BEIS approach for Oil Price Assumptions

	Short term (2017-2018)	**Medium term (2019-2030)**	**Long term (2030 onwards)**
Stress Test	Flat at $35		
Low Prices	Using Options Pricing implied distribution to derive range	Interpolate to Long Run Low	IEA 450 scenario demand for 2030 intersected with BEIS high supply curve
Central Prices	Futures curve	Interpolate to Long Run Central	IEA New Policies scenario demand for 2030 intersected with BEIS central supply curve
High Prices	Using Options Pricing implied distribution to derive range	Interpolate to Long Run High	Inelastic portion of the low supply curve

6 We aggregate the long run oil supply curves provided by Wood Mackenzie to $5 tranches (rounding up).

Short Term Assumptions

12. The central oil price assumption for 2017 is calculated as an averaged of the closing prices for i) the outturn price for January to March monthly contracts and ii) monthly futures contracts from April to December 2017. For 2018 we averaged the daily closing prices for monthly futures contracts from January to December 2018. All averages were calculated on the closing prices of each future contract from 20 February 2017 to 31 March 2017 (30 trading days).

13. For the High and Low price assumptions for 2017 and 2018 we used the Bank of England's data on the pricing of options and implied volatility available at the end of March 2017[7]. To determine the High and Low prices we selected a confidence level of 75% i.e. we estimate that at the end of March 2017 the market attached a 75% likelihood that the oil price will fall within the High-Low price range for each of 2017 and 2018. The confidence interval is designed to reflect plausible alternative outcomes for the oil price rather than focusing on the extremes (which would result for example from using a 95% confidence level).

14. Our 2017 short term prices assumptions are higher than the 2016 assumptions across the three scenarios. At $54/bbl in 2017 and $53/bbl in 2018 the Central assumption is mainly driven by the higher outturn and forward prices generated by the OPEC production cut agreed in late 2016, counterbalanced to some extent by strong US oil production. The low price assumption reflects a case where the US LTO production keeps increasing and where OPEC cuts continue only until the end of 2017. Finally, the High price assumption mainly reflects a scenario where OPEC strategic management produces substantial market tightness, but the US is unable to compensate the market shortness.

Medium and Long Term Assumptions

15. To obtain the low, central and high oil price assumptions for the 2019-2030 period we linearly interpolated from the 2018 values to the long run 2030 price levels. Beyond 2030 we maintained the price levels unchanged, given the long term uncertainties. This trajectory deliberately simplifies the complex market dynamics, as BEIS focuses on generating assumptions for long run oil prices, and not on generating market scenarios or modelling cycles. To derive the 2030 price assumptions we intersected different supply and demand curves to arrive at implied long run equilibrium prices, as described below.

Oil supply curves

16. In 2016 Wood Mackenzie provided estimates of long run oil supply curves including sensitivities around the central supply curve to establish a 'high supply' case (i.e. a supply curve with higher volumes of oil produced at any given price level), and a 'low

[7] More detail can be found in the technical appendix of Bank of England working paper: Recent developments in extracting information from options markets (2000). http://www.bankofengland.co.uk/archive/documents/historicpubs/qb/2000/qb000101.pdf

supply' case (i.e. a supply curve with lower volumes provided at any given price level) to capture the uncertainty over the long term and a plausible range of alternative supply cases[8]. On the advice of the expert panel, we agreed that the supply curves were still a reliable basis to inform the 2017 fossil fuel price assumptions.

17. For the 2016 price assumptions the original Wood Mackenzie supply estimates were modified to reflect the latest developments in the oil sector[9]. On the advice of the expert panel when deriving the 2017 supply curves we have retained these modifications, and have introduced further changes to reflect the following uncertainties:

    - *Outlook for production in Iran*. In light of uncertainties surrounding oil exploration and production in Iran for the central and the low supply curves we have reduced expected total productive capacity for 2030 from around 6 million barrel per day (mb/d) to 5mb/d. We have left unchanged our 2016 outlook for the high supply curve.

    - US *Light Tight Oil (LTO) production growth*. LTO in the US has constantly exceeded production forecasts and more recently it has proved capable of counterbalancing some of the tightness generated by the OPEC/non-OPEC production cuts. In light of this more optimistic prospect for LTO, in our central supply case we are assuming that US LTO will provide around 10 mb/d in 2030 (compared to around 8 mb/d in our 2016 assumptions). The increases across the high and low supply cases lead respectively to about 5 mb/d and 8mb/d of production from US LTO. In the high supply/low price case the prospects for US LTO are less optimistic because competitive alternative supplies provide significantly larger volumes of infra-marginal supply. The low supply/high price case is driven by less optimistic prospects on cost reductions in the long term.

Oil demand curves

18. On the demand side BEIS considered the following 2030 IEA total liquid projections derived from their World Energy Outlook 2016:

    - Current Policy Scenario: 109mb/d
    - New Policy Scenario: 103mb/d
    - 450 Scenario: 90mb/d

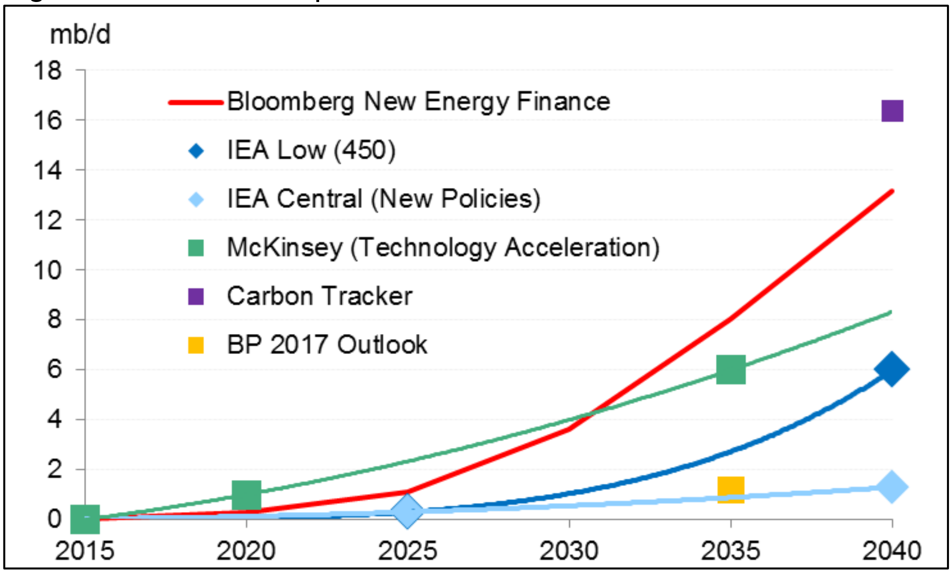
19. On the advice of the panel we reviewed the appropriateness of IEA demand scenarios by comparing them to the demand projections of other organisations (see Annex B). We also considered whether the variation in the IEA demand scenarios sufficiently captured two key uncertainties in long term oil demand: the potential growth in electric vehicles and the increase in demand from the petrochemicals industry.

[8] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/565992/BEIS_WM_Fossil_Fuel_Supply_Curves_Final_Report.pdf

[9] Page 9 of the 2016 BEIS Fossil Fuel Assumptions: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/576542/BEIS_2016_Fossil_Fuel_Price_Assumptions.pdf

20. Overall, BEIS concluded that while there is a wide range of views for future oil demand, the IEA scenarios are sufficiently wide to capture the key uncertainties. Following the advice of the panel, BEIS compared several projections of electric vehicles uptake in terms of oil demand displaced (see Figure 2). Even under the most optimistic scenarios BEIS sees no evidence that in 2030 the volume of crude oil displaced is sufficient to completely reshape the outlook for 2030 prices. In respect to the evolution of demand from the petrochemical sector, BEIS noted that many projections refer to the significant uncertainty and potential of the sector. Nonetheless, the projections of demand reviewed showed values broadly comparable to those identified by the IEA.

Figure 2: Crude oil displacement from Electric Vehicles



Source: BEIS Analysis on BNEF New Energy Outlok 2016, IEA 2016 World Energy Outlook, Mc Kinsey Global Energy Perspective 2016 presentation, Carbon Tracker "Expect the Unexpected" report, BP 2017 Energy Outlook

Medium and long term oil price assumptions

21. The medium and long term BEIS oil price assumptions intend to capture the most plausible range of oil prices until 2030. Overall, the variation captured in the high and low price assumptions reflects market uncertainty around the future of OPEC strategic management, the strength of US production and the prospects for demand (closely linked to global economic growth).

22. The Central price assumption results from intersecting the IEA New Policies Scenario demand with our central supply curve and the resulting assumption is unchanged from 2016 at $80/bbl (per barrel). This continuity reflects our expectation that the central supply curve will continue to be relatively elastic at that price level.

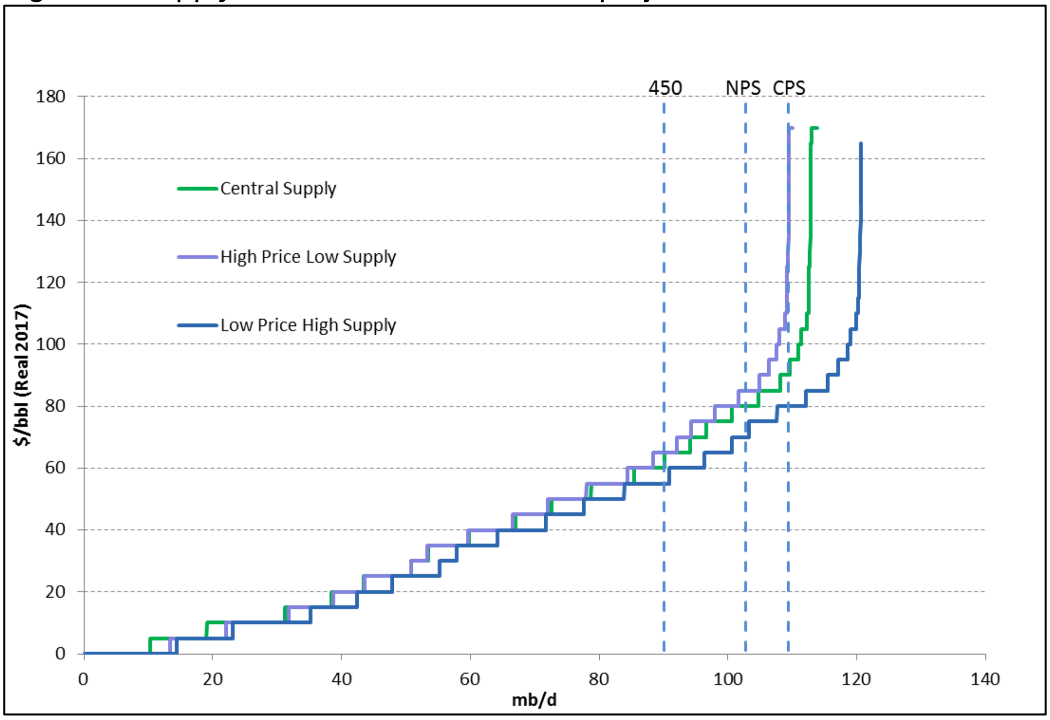
23. The low price assumption combines the IEA 450 demand scenario and the 'high supply' case and is unchanged at $55/bbl. This value reflects a case of more limited increase in US LTO production caused by limited demand and low prices driven by relatively more competitive OPEC supplies.

24. The High price assumption combines the IEA Current Policies demand scenario with the 'low supply' case. This reflects a world where supply would be less responsive to

high prices, due to higher costs of production and lower technological improvement, combined with a world where action to fight climate change progresses at a lower pace than currently expected.

25. In this scenario the demand and supply curves would produce extremely high prices as they do not intersect (See Figure 3). On the advice of the panel, we have assumed a long run high price of $120/bbl price in real terms. This reflects a judgement that beyond $120/bbl it is plausible to assume that the oil industry is able to significantly increase productive capacity to meet demand, and that there are structural adjustments to demand towards alternative energy supplies if no additional supplies are available.

Figure 3: Supply curves and IEA Demand projections



Source: IEA, Wood Mackenzie

The low “Stress Test"

26. The low “stress test” price assumption is designed to assess policies in a world of sustained very low oil prices. The stress test reflects the historical experience that the oil price can deviate from the evidence on long run equilibrium values for long periods, as it did from the mid-1980s. To derive the 2017 low “stress test” price we have used the same methodology as in 2016[10], which results in a price of $35/bbl (compared to $30/bbl last year). The change is due to rebasing of prices to real 2017 prices (from real 2016 prices) rather than structural changes.

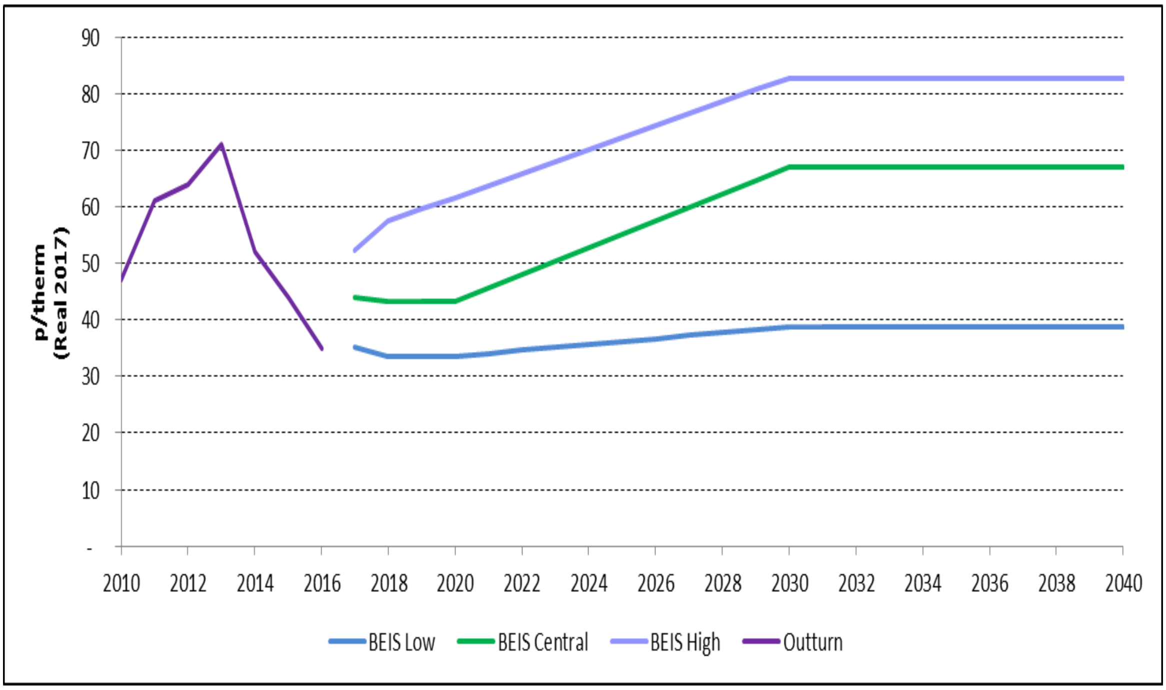
[10] Oil prices flat in real terms at their average from 1986 to 2003. See para 28 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/576542/BEIS_2016_Fossil_Fuel_Price_Assumptions.pdf

Gas Price Assumptions

Table 3: 2017 BEIS gas price assumptions

p/therm	2017 BEIS Gas price assumptions		
Real 2017 prices	**Low**	**Central**	**High**
2017	35	44	52
2018	34	43	57
2019	34	43	60
2020	34	43	62
2021	34	46	64
2022	35	48	66
2023	35	50	68
2024	36	53	70
2025	36	55	72
2026	37	58	74
2027	37	60	76
2028	38	62	79
2029	38	65	81
2030	39	67	83
2031	39	67	83
2032	39	67	83
2033	39	67	83
2034	39	67	83
2035	39	67	83

Figure 4: BEIS Gas Price Assumptions



Modelling approach

27. The approach used to create BEIS's gas price assumptions combines: (a) forward prices and options data for the short term and (b) evidence on the long run costs of gas production and estimates of long run gas demand to arrive at long run implied equilibrium prices.

28. The reason for using forward prices over the short term (2017-2018) is that they reflect expectations of market participants about gas supply and demand over this time horizon. In the long run the price assumptions are anchored at the expected cost of marginal gas supplies to European markets at projected levels of European gas demand. This is a long run market equilibrium condition. The table below summarises the approach which is explained in more detail in subsequent sections.

Table 4: 2017 BEIS Gas price assumptions approach summary

	Short term **(2017-2018)**	**Medium term** **(2019-2030)**	**Long term** **2030 onwards**
Low Prices	Using Options volatility to derive low range	Flatline to 2020 then interpolate to Long Run Low	IEA 450 scenario demand intersected with BEIS high supply curve
Central Prices	Forward curve	Flatline to 2020 then interpolate to Long Run Central	IEA New Policies scenario demand intersected with BEIS central supply curve
High Prices	Using Options volatility to derive high range	Interpolate to Long Run High	IEA Current Policy scenario demand intersected with BEIS low supply curve

29. The assumptions based on this evidence are compared with the demand projections and price forecasts of other organisations (see Annex B and C) which BEIS uses to inform its judgement. Whilst it is beyond the scope of this report to analyse the projections of other institutions in detail it is clear that there is a wide range of views and BEIS's central assumption lies within that range. All data are in real 2017 prices (pence/therm).

Short Term Assumptions

30. The central gas price assumption for 2017 is calculated as an average of outturn NBP spot prices for Q1 2017 and the quarterly forward curves for Q2, Q3 and Q4 2017, averaging the market data over the period from 20 February 2017 to 31 March 2017 (30 trading days). The 2018 central assumption is based on the average of the corresponding four quarterly forward contracts (Q1, Q2, Q3 and Q4 2018) using the same market data period.

31. The forward market shows prices as broadly flat between 2017 and 2018, in part reflecting increasing global Liquefied Natural Gas (LNG) supply. However, short term market prices remain higher than in the 2016 set of assumptions.

32. On the advice of the expert panel, we have opted to use the forward curve only for the first two years, because beyond this horizon liquidity (the volume of traded contracts) begins to fall and therefore may not offer the same opportunity for price discovery.

33. High and Low price assumptions are derived as a range around the 2017 and 2018 central price assumptions using data on NBP options volatility.[11] Using implied volatility, we have selected a confidence level of 75% i.e. suggesting that the market at March 2017 attached a 75% likelihood that the gas price will fall within High-Low price range for each of 2017 and 2018. The choice of the 75% confidence interval is designed to reflect plausible alternative outcomes for the gas price rather than focusing on the extremes (which would result for example from using a 95% confidence levell).

Medium Term Assumptions

34. For the central and low price assumptions, we flat line prices in 2019 and 2020 at their 2018 level. In the short term the market is considered to be out of (long term) equilibrium. Forward prices and external projections imply this will take longer than two years to resolve, as seems consistent with for example the increased LNG supply due to be commissioned over the rest of this decade. Flat lining for 2019 and 2020 allows more time for the market to start to adjust towards the long term prices. We have flat lined rather than using the forward curve for 2019 and 2020 as given limited market liquidity for these years, we judge that 2018 forward prices are a more reliable data point and guide to market future expectations for this period.

35. We also tested the low price assumptions for this period against a potential “price floor” of short term US LNG export cash costs. This reflects a floor price at which US LNG imports would be curtailed (the price would just cover the short run marginal costs of supply) which would be expected to support prices. While there are some uncertainties

[11] Replicating an Energy Information Administration (EIA) approach, we derived confidence intervals around expected futures prices using the “implied volatilities” of options. Further information can be found in Annex D of the BEIS 2016 Fossil Fuel Assumptions report.
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/576542/BEIS_2016_Fossil_Fuel_Price_Assumptions.pdf

in estimating this floor price,[12] the values suggested are similar to our low price assumptions.

36. After 2020 the central and low price assumptions are linearly interpolated to their long run equilibrium values in 2030.

37. For the high price assumption, we have assumed faster adjustment of prices towards the (higher) long term equilibrium. This, for example, reflects more rapid growth in demand which would tighten the market more quickly. The high price assumption has therefore been constructed by linearly interpolating from 2018.

Long Term Assumptions

38. There is uncertainty about how European and UK gas prices could develop over the medium and long term as they are influenced by a number of factors. Global LNG capacity is expected to grow strongly to 2020 and therefore even with global gas demand growth the market is likely to be well supplied into the early 2020s. However, there are major uncertainties around Russia's pricing strategies and developments in US and Asian demand, which in turn could affect the amount of LNG available to the European market.

39. To inform the 2016 fossil fuel price assumptions, we appointed Wood Mackenzie to produce scenarios for the evolution of long run supply curves for gas to European markets.[13] The supply curves were built up from breakeven costs for investment/long run marginal costs for the key categories of supply. Some of these uncertainties mentioned above have been captured in the composition of the supply curves. On the advice of the expert panel, it was agreed that the supply curves were still reliable to inform the 2017 fossil fuel price assumptions as there had been no fundamental changes in the long run supply outlook.

40. The only significant change BEIS made to the supply curves has been the assumptions of the costs of US LNG supply to Europe. The potential size of US LNG exports, their pricing flexibility, and the proximity to Europe (compared to Asia) means US LNG has the potential to be a key driver of European gas prices. The cost of US LNG is assumed to be the Henry Hub price plus the price of delivery to Europe – this includes liquefaction, shipping and re-gasification. We have revised down the $4.8/mmbtu long term assumption for Henry Hub prices used for the 2016 central gas price assumption to $4.2/mmbtu for the 2017 central gas price assumption, which is aligned with Wood Mackenzie's December 2016 Henry Hub projection for 2030. This reflects the continuing drop in US gas production costs and abundant low cost resource available in North America. As in 2016, we have assumed the 2030 Henry Hub price could be $1/mmbtu higher or lower than the central assumption for the low and high gas price assumptions.

[12] Cash cost breakdown of US LNG to Europe suggested by the Panel members: Henry Hub price + 15% per contract + $0.3 for shipping costs + $0.4 regasification costs. Based on range of short run Henry Hub price forecasts, of which the lowest was $3, the price floor is estimated to be around $4.15/mmbtu (or 32p/therm).

[13] At https://www.gov.uk/government/publications/fossil-fuel-price-assumptions-2016

41. The long term gas price assumptions combine the three updated long term supply outlooks with the three long term demand projections for European gas demand from the IEA World Energy Outlook 2016. The geographical coverage of “Europe” used for the Wood MacKenzie gas supply curves provided to BEIS differs from the IEA’s and we have therefore adjusted the IEA’s demand projections to allow for the difference in coverage.[14]

42. For the low, central and high assumptions, a flat line for gas prices in the period after 2030 has been assumed. This trajectory is clearly a simplification, with the possibility that very long term prices could trend up reflecting the need to access more expensive sources of supply, or trend down reflecting technological improvement or declining demand. However, given there is less visibility on potential gas supply conditions post 2030, we have chosen to anchor our long term assumptions based on evidence for 2030. Figure 2 presents the implied prices by combining supply curves and adjusted IEA OECD Europe gas demand estimates. All data are in real 2017 p/therm.[15]

Central Price Assumption

43. For the 2030 Central price assumption we have combined the IEA New Policies scenario demand with the central 2030 supply curve. We have therefore assumed for the central assumption that in the long run the supply side, in particular US LNG supply is relatively flexible and responsive to price although we have also assumed Russia continues to price strategically, albeit constrained by supplies from other sources including US LNG.

Low Price Assumption

44. The Low price assumption is illustrative of a world where there is substantial demand reduction for fossil fuels including gas due to for example increased policy action to mitigate climate change. For the 2030 Low price assumption we combine low demand with high supply: i.e. the IEA 450 scenario demand (the lowest level of gas demand of the three IEA scenarios) and the ‘high supply’ case provided by Wood Mackenzie.

45. This demand and supply combination is plausible because if gas demand is low, it is plausible that US wholesale gas prices and US LNG costs would be lower and that Russia would be driven towards competing on price to maintain sales volumes.

High Price Assumption

46. For the 2030 High price assumption we combine the IEA Current Policies scenario demand level with the ‘low supply’ 2030 supply curve. We have therefore assumed

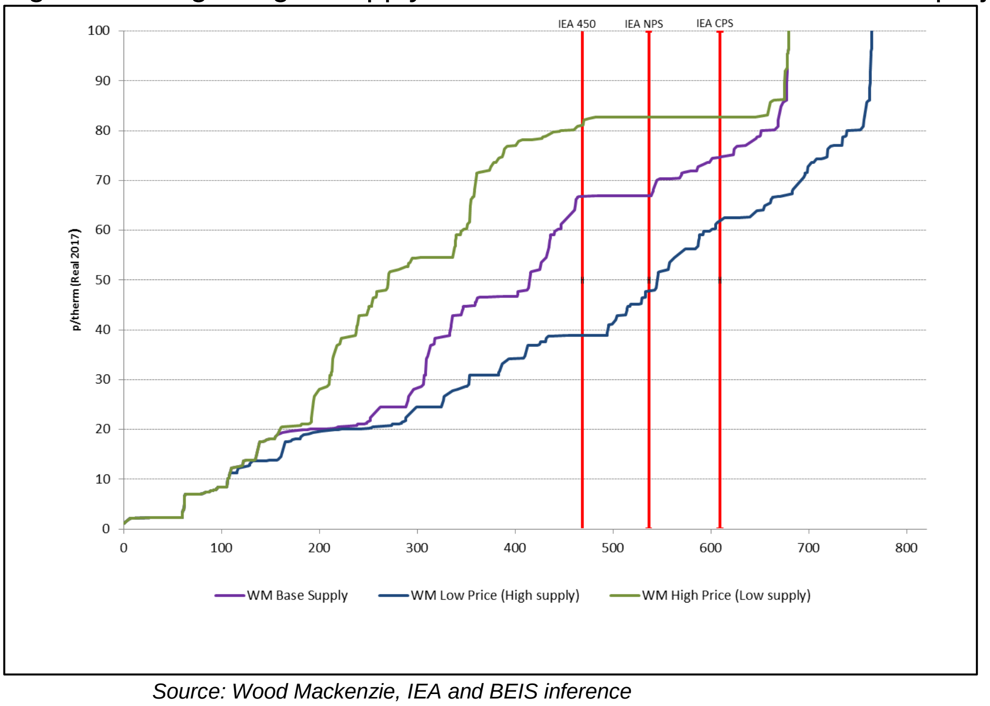
[14] Wood Mackenzie’s “Europe” region had additional countries, which included: Albania, Bosnia, Bulgaria, Canary Islands, Croatia, Latvia, Lithuania, Macedonia, Romania and Serbia. The adjustment was applied based on historical 2015 gas consumption for these addional countries. Further information on the methodology for adjustments to IEA demand projections can be found in Annex E of the BEIS 2016 Fossil Fuel Price Assumptions.

[15] The supply curves provided by Wood Mackenzie were in real 2015 $/mmbtu. These were converted to p/therm using OBR’s exchange rate forecasts published in their Economic and fiscal outlook – March 2017 (1.31 USD:GBP based on 2021 forecast flatlined) and to 2017 prices using the OBR March 2017 forecast.

higher US wholesale gas prices limit the competitiveness of US LNG which in turn enables Russia to sustain a higher price for its gas supplies.

47. This demand and supply combination is plausible because if gas demand is high it is plausible that US wholesale gas prices and US LNG costs would be higher and that Russia would be able to target a price just below (higher) marginal US LNG costs to maximise profits without having to sacrifice sales volumes.

Figure 5: Long run gas supply curves combined with IEA demand projections



Source: Wood Mackenzie, IEA and BEIS inference

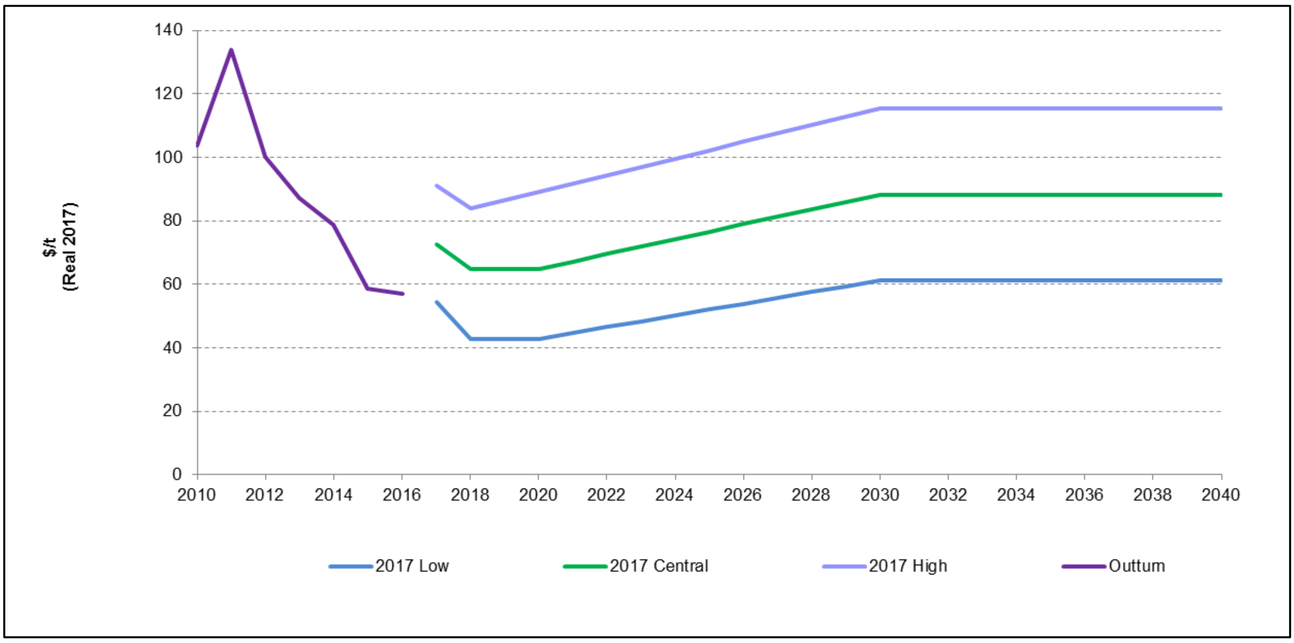
48. Beyond 2030 we maintain the price levels unchanged, given the long term uncertainties. Given there is less visibility on potential gas supply conditions post 2030, we have chosen to anchor our long term assumptions based on evidence for 2030.

Coal Price Assumptions

Table 5: BEIS 2017 coal price assumptions

$/t	**2017 BEIS Coal price assumptions**		
Real 2017 prices	**Low**	**Central**	**High**
2017	54	73	91
2018	43	65	84
2019	43	65	87
2020	43	65	89
2021	45	67	92
2022	47	70	94
2023	48	72	97
2024	50	74	100
2025	52	77	102
2026	54	79	105
2027	56	81	107
2028	58	84	110
2029	59	86	113
2030	61	88	115
2031	61	88	115
2032	61	88	115
2033	61	88	115
2034	61	88	115
2035	61	88	115

Figure 5: BEIS Coal Price Assumptions



Modelling approach

49. The approach used to derive BEIS's coal price assumptions combines (a) forward prices and errors of historic forward prices for the short term and (b) evidence on the long run costs of coal production and long run coal demand to arrive at a long run implied equilibrium price.

50. The table below summarises the approach taken for the low, central and high price assumptions. The methodology is explained in more detail in subsequent sections[16].

Table 6: Summary of BEIS approach for coal price assumptions

	Short term **(2017-2018)**	**Medium term** **(2018-2030)**	**Long term** **(2030 onwards-2040)**	**Key Assumptions**
Low Prices	Forward prices adjusted downwards.	Flatline to 2020 then a linear interpolation to long run low price assumption.	IEA 450 demand scenario intersected with BEIS high coal supply curve.	Increased South African supply to Europe (50%). Demand based on IEA 450 scenario.
Central Prices	Based on forward price curve.	Flatline to 2020 then a linear interpolation to long run central price assumption.	IEA New Policies demand scenario intersected with BEIS central coal supply curve.	10% of South African and 5% of Mozambican coal available to Europe. Demand based on IEA New Policies Scenario.
High Prices	Forward prices adjusted upwards.	Linear interpolation to long run high price assumption from 2018.	IEA Current Policies demand scenario intersected with BEIS low coal supply curve.	Decreased Russian supply available to Europe (90%). Demand based on IEA Current Policies Scenario & EU Energy Trends.

[16] In all coal price scenarios, the quality of coal has been standardised to the benchmark ARA specification of 6322 kcal/kg gross as received (gar) / 6000 kcal/kg net as received (nar).

Short term Assumptions

51. The central coal price assumption for 2017 is derived from a weighted average of CIF ARA outturn prices Q1 2017, and the quarterly forward curve for Q2, Q3 and Q4 2017, averaging over the data resulting from the 30 days trading period to 31 March 2017. The 2018 central coal price estimate is derived from the average of year ahead forward prices for 2018 traded over the same period. Forward prices aggregate the future price expectations and insights of market participants; as such, they are taken to be the best indicator for short term coal price movements.

52. The increase in coal spot and forward prices in the second half of 2016 was primarily driven a decision by the Chinese Government to reduce production by limiting coal mines to 276 days of operation per year. Supply was further tightened by adverse weather conditions in Australia and Indonesia, two key coal suppliers to Asia. Because coal consumption in the largest consumers such as China and India dwarfs European import demand, changes in demand in these countries can cause large price movements in the European coal market. China has subsequently relaxed the production constraints, allowing its domestic coal mines to return to 330 days of operation per year. Although China does intend to continue to reduce capacity over the next few years, it has suggested it will not return to a blanket 276-day limit on mines, but use other measures to target a price of Rmb500-575/t ($75-86/t)[17].

53. High and low coal prices are estimated from the historic deviation between the quarterly and year ahead forward curves and respective outturn prices between 2007 and 2016. Both high and low price assumptions are calculated on the basis of one standard deviation of historic forward price errors. The low and high price assumptions are designed to reflect plausible alternative outcomes for the coal price rather than focusing on the extremes.

Medium term Assumptions

54. For the central and low price assumptions, we assume prices remain at their 2018 level in 2019 and 2020. We consider there is too little liquidity in the coal forward price curve beyond 2018 to act as a reasonable forecast of future prices. Given the current global spare capacity in coal markets we continue as last year to assume coal prices do not move upwards to their long run “equilibrium” values until after the end of the decade.

55. After 2020 the central and low price scenarios are linearly interpolated to their long run equilibrium values in 2030.

56. The high price scenario is linearly interpolated towards its long term 2030 equilibrium value from 2018. This reflects the possibility that coal prices may not only reach a higher equilibrium price, but that the European coal market may move more rapidly towards this price.

[17] Using an exchange rate of 1 Rnb=0.15 USD

Long term Assumptions

57. The long run market balancing condition requires that the market price that consumers are willing to pay must cover the full cost (i.e. including capital costs) of the marginal supply if investment in that capacity is to be made. We have therefore anchored price scenarios around the estimated long run marginal cost of seaborne steam coal imports to Europe in 2030 given an estimated level of demand for coal imports, with a delivery point of ARA.

58. We have used the same set of supply curves provided by Wood Mackenzie for BEIS's 2016 coal price assumptions, as we consider the fundamentals of long run coal supply have not materially changed in the past year. The supply curves were built up from breakeven costs for investment/long run marginal costs for the key categories of supply. They reflect variation in the technical/ geological/country characteristics and were based on a mine by mine analysis. Breakeven costs were also categorised by country and type of resource and exclude sunk and committed investment costs. Further detail on the construction of the long run coal supply curves is provided in the Wood Mackenzie report published alongside last year's publication[18].

59. The key driver of long run European supply variation between the three scenarios is the proportion of coal that 'swing suppliers' such as South Africa and Russia export to Asia rather than Europe. This in turn is affected by the level of Asian coal demand, driven by factors such as environmental regulation, the level of non-coal power generation capacity and electricity demand.

60. Estimates of coal demand are derived from the 'New Policies', 'Current Policies' and '450 degree' scenarios in the IEA's World Energy Outlook 2016. The IEA provides forecasts of coal demand for OECD Europe. This region matches the region that would consume the seaborne supplies of coal to Europe estimated by Wood Mackenzie. However two adjustments to the IEA demand estimates are required to match coal supply and demand to derive price estimates for European steam coal imports. First, European coal production must be netted off coal demand in order to obtain demand for coal imports. We have used projections of coal production in OECD Europe from the IEA's World Energy Outlook 2016 to do this. Second, the demand for steam coal must be separated from demand for other types of coal such as lignite and metallurgical coal in order to be consistent with supply estimates.[19]

Central Price Assumption

61. In the central case, Columbia is expected to be the key supplier of low cost coal in to Europe, with Russia offering the majority of higher cost supplies. Lower levels of coal of

[18] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/565992/BEIS_WM_Fossil_Fuel_Supply_Curves_Final_Report.pdf

[19] Metallurgical coal is netted off using the estimate of the proportion of European coal demand accounted for by metallurgical coal in 2019 from the IEA Medium Term Coal Outlook 2016 (2020 is used as this report does not predict trends beyond this year). Lignite coal demand has been removed by netting off European coal production, as trading of lignite is very limited due to its low energy content relative to its weight. This approach towards estimating seaborne coal import demand implicitly assumes that there are no net imports/exports to/from OECD Europe by rail, which is reasonable as Russia is unlikely to supply coal to OECD European countries via rail.

varying cost are expected from the US and South Africa, with Venezuela and Mozambique offering small amounts of relatively expensive coal supplies.

62. This level of coal supply is consistent with Asian coal demand in the IEA's 'New Policies scenario', which forecasts demand to grow primarily in India and southeast Asia. This in turn means that only 10% of South African coal and 5% of Mozambican coal is expected to be available to Europe, with the remainder being exported to the Pacific basin.

63. European coal demand for the long run central price assumption is estimated from the IEA's 'New Policies scenario'. In this scenario, the EU ETS develops in accordance with the 2030 Climate and Energy framework, with emissions reductions targets in this framework leading to strengthened support for renewable electricity generation. This demand scenario is consistent with the proportion of coal that swing suppliers sell to Europe falling from their current levels, as the decrease in European demand makes the Asian market more attractive for these suppliers.

Low Price Assumption

64. The high supply/low price supply curve is constructed on the same basis as in the central case, with the difference that 50% (rather than 10%) of South African coal is available to the European market. This assumption is based on lower Asian demand which would be consistent with, for example, a prolonged economic slowdown in China, and tighter environmental regulation in Asia.

65. Demand is estimated using the IEA '450 scenario' for OECD Europe, which is lower than demand in the New Policies scenario. This scenario assumes that the EU ETS is strengthened in line with the 2050 roadmap for Europe, as well as greater support for renewables than in the 'New Policies scenario'. Combining this low demand scenario with a high supply curve is plausible, but, as noted above, would likely require a significant increase in environmental action from governments in Asia.

High Price Assumption

66. Long run supply for the high price/low supply case is constructed assuming that 10% of western Russian coal is exported to Asia; in the central case all western Russian coal is exported to Europe. This would be consistent with potential transport infrastructure developments going ahead in Russia to increase its capacity to export coal eastwards, and increased economic growth in Asia.

67. Demand in the high scenario is estimated using the IEA 'Current Policies scenario'. Policies such as the EU ETS and renewables subsidies are assumed to remain in line with the 2020 Climate and Energy Package, and other policy commitments such as the Industrial Emissions Directive are continued.

68. The IEA's 'Current Policies scenario' projects an ARA coal price of $80/t for 2030 which is lower than our 2017 high price coal assumption for 2030. This is material given estimates of breakeven costs of European coal production (for example the IEA 2016

Medium Term Coal Outlook reports a production cost reduction in the Polish coal sector to PLN 257/t – c.$66/t – in 2015) which suggest that higher prices than the $80/t in 2030 would incentivise substantial extra supply[20].

69. To model this supply reaction, we have used European coal production figures from EU Energy Trends to 2050, which forecasts the ARA coal price to incease from c.80/t in 2020 to almost $140/t by 2050, so will be more in line with our high price assumption in 2030. Using EU Energy Trends data on European coal production rather than the IEA 'Current Policies scenario' reduces import demand by around 17Mt, resulting in a high coal price assumption of $115/t in 2030.

70. This higher demand scenario could materialise simultaneously with lower supply to Europe if, for example, lower European environmental regulation is combined with increased rates of Asian economic growth, which attract greater proportions of coal supply to Asia.

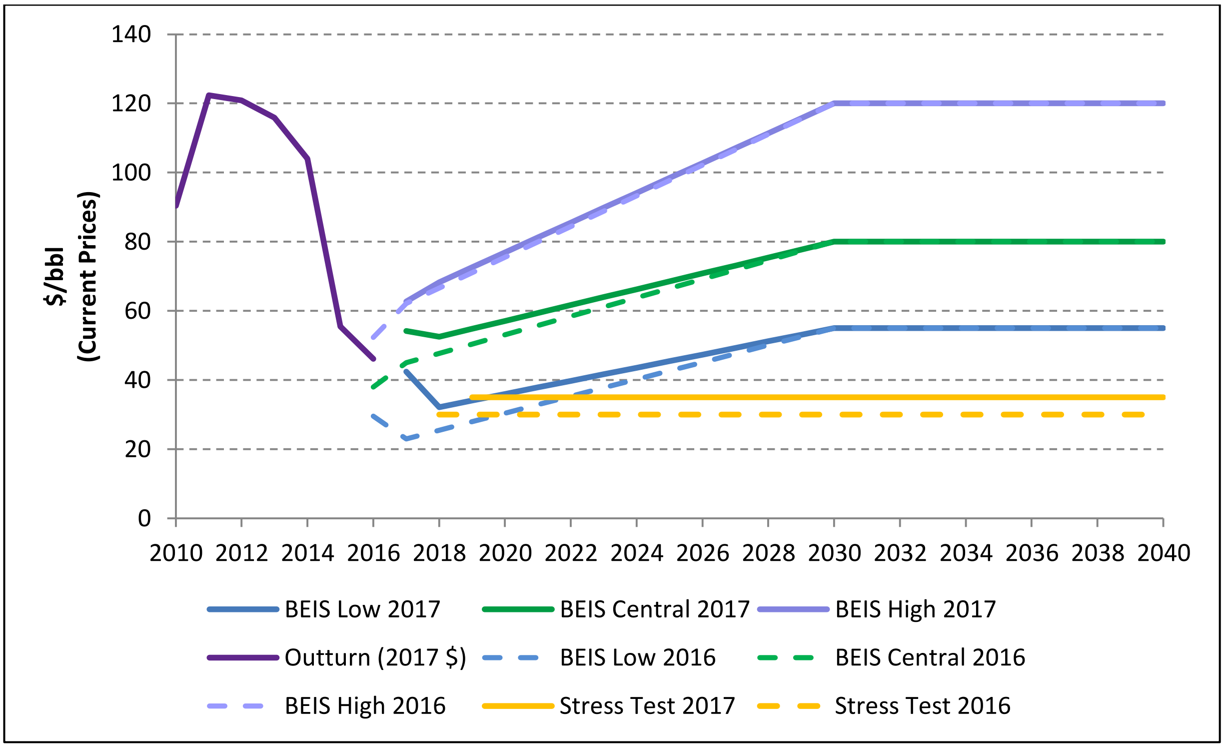
71. Beyond 2030 we maintain the price levels unchanged, given the long term uncertainties.

[20] Based on an exchange rate of PLN=0.26 USD

Annex A – Comparison with 2016 BEIS Fossil Fuel Price Assumptions

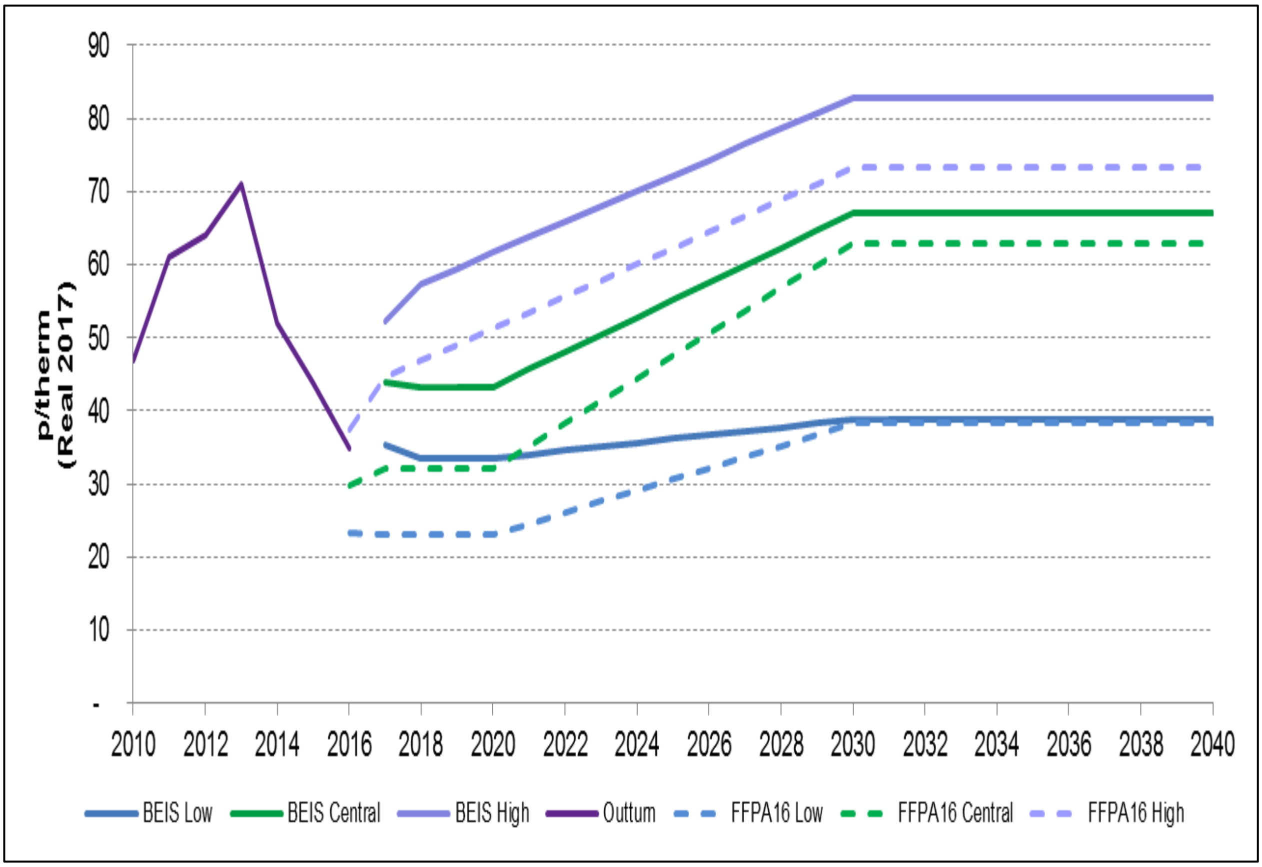
Oil Price Assumptions

The 2017 Oil Price Assumptions differ from those of 2016 with respect to the short term assumptions and the long term stress case test. The short term change in the assumptions arises mainly from the bullish impact of the OPEC production cuts on the Brent forward curves, together with more optimistic prospects for economic growth. The additional supplies from the US LTO are counterbalancing this tightening trend, with volumes of competitive supplies constantly beating forecasts. In the long run the supply and demand outlooks to 2040 are unchanged. The long term structural dynamics are very similar to those of 2016. While there are increases to US LTO forecast, most of the production is infra marginal, leaving clearing prices unaltered. The stress case has increased by $5/bbl, driven by price inflation adjustments.



Gas Price Assumptions

The 2017 Gas Price assumptions are higher than the 2016 assumptions due to market developments in the short term and updated exchange rate assumptions. In the short run the upward revision reflects the forward curve - prices have climbed reflecting market expectations – some of this is due to continuing maintenance work at Rough storage, depreciation of pound , colder weather (over Jan 17) and coal prices increasing. Evidence on the long run marginal cost of supply (in $/mmbtu) has not changed significantly. The upward revision is reflecting the change in the exchange rate assumption. As for the 2016 assumptions the high and low scenarios are not symmetric in the long run as they are based on different assumptions around Russia's strategy, Henry Hub prices and LNG available to the European market. In addition, for the central and low price assumptions, we flat line prices in 2019 and 2020 at their 2018 level. We have flat lined rather than using the forwards curve for 2019 and 2020 as given limited market liquidity for these years, we judge that 2018 forward prices are a more reliable data point and guide to market future expectations for this period.

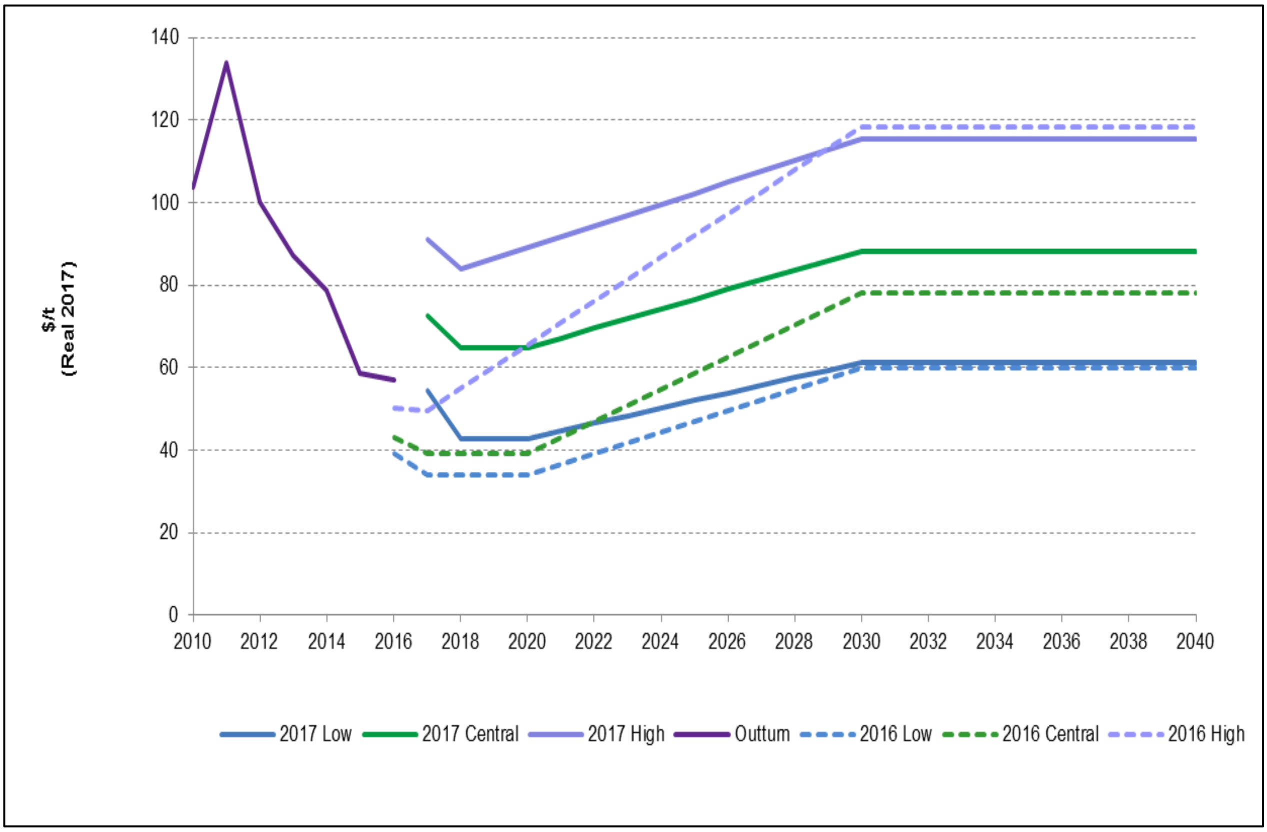


Coal Price Assumptions

The 2017 Coal Price assumptions are higher than the 2016 assumptions in the short term due to a sharp increase in coal spot and forward prices in the second half of 2016. This market movement resulted from a worldwide fall in coal production, particularly in China. Price arbitrage opportunities have led coal exporters to divert supplies from Europe to Asia, thus increasing the European ARA coal price.

In addition, the BEIS low assumptions for coal are based on 1 standard deviation of historic forward price errors, rather than the 0.5 standard deviation used last year. The confidence interval was reduced on the low side last year because there was limited scope for prices to fall further given how low spot prices were when we produced the assumptions last year; now that coal prices have risen, a we consider a symmetric confidence interval of +/- 1 standard deviation is appropriate.

The long run central coal price assumption has increased due to higher import demand projections for OECD Europe from the IEA, resulting from a fall in expected domestic European coal production. Low and high assumptions in the long run remain largely unchanged, although the methodology for the high price assumption has changed slightly as described in paragraphs 68-69 above. OECD European import demand projections from the IEA's 450 scenario are similar to the previous year's projections.



Annex B – Demand Projections

The tables below compare demand projections from key energy institutions and companies where information is publically available[21]. Whilst we acknowledge that there are significant uncertainties with demand projections we have chosen to use IEA demand projections as they are internationally recognised as a leading institution in energy demand and supply projections. In addition, the IEA WEO 2016 demand range broadly captures most external demand projections across the fuels.

Oil

Oil* Demand Projections (mb/d) (conversion rates where used are indicated below the table)				
Source	**Published**	**2020**	**2030**	**2040**
IEA WEO 2016 (New Policies)	Nov-16	98	103	108
IEA WEO 2016 (450)	Nov-16	95	90	82
IEA WEO 2016 (Current policies scenario)	Nov-16	99	109	121
IEA MTO 2017	Mar-17	102	-	-
EIA IEO 2016 (Reference)	May-16	100	109	121
EIA IEO 2016 (High oil price)	May-16	97	106	119
EIA IEO 2016 (Low oil price)	May-16	103	111	123
OPEC WOO 2016 (Reference)	Sep-16	98	106	109
BP Outlook 2017**	Jan-17	*101*	*109*	-
WEC 2016 ("Unfinished Symphony")	Oct-16	-	94	-
WEC 2016 ("Hard Rock")	Oct-16	-	101	-
WEC 2016 ("Modern Jazz")	Oct-16	-	103	-
Statoil - Low demand - Renewal scenario***	Jun-16	-	93	-
Statoil - Reference demand - Reform scenario***	Jun-16	-	106	-
Statoil - High demand - Rivalry scenario***	Jun-16	-	112	-
ExxonMobil Outlook For Energy	Dec-16	100	108	112

** All oil data refers to total liquids (crude oil, Natural Gas Liquids and biofuel) except Statoil which excludes biofuels.*
*** BP data was provided in MToe, and was converted using a MToe/Mb/d Rate of 45.7(2020), 45 (2030)*
**** Data in Mb/d is not directly referred to in the publication and was provided bilaterally by Statoil*

[21] As of 31 March 2016.

Gas

Global Gas Demand Projections (bcm)						
Source	**Published**	**2020**	**2025**	**2030**	**2035**	**2040**
IEA WEO 2016 (New Policies Scenario)[22]	Nov-16	3802	4106	4466	4858	5219
IEA WEO 2016 (Current Policies Scenario)[23]	Nov-16	3866	-	4726	-	5713
IEA WEO 2016 (450 Scenario)	Nov-16	3796	-	4062	-	4008
BP Outlook 2017[24]	Feb-17	3930	4212	4541	4789	-
ExxonMobil 2017 energy outlook	Dec-16	-	4194	-	-	4972

Coal

External projections of European import demand for thermal coal, 2020-2040 (Mt) [25]				
Source	**Published**	**2020**	**2030**	**2040**
IEA WEO 2016 (New Policies)	Nov-16	166	151	118
IEA WEO 2016 (450)	Nov-16	143	85	79
IEA WEO 2015 (Current Policies)	Nov-16	154	173	189
EIA Annual 2015 (Reference)	Apr-16	177	-	152

[22] IEA NPS figures taken from Annex A of WEO page 549 (Demand matches production)
[23] IEA 40 and CPS scenarios provided through email by IEA
[24] BP figures were provided in Mtoe and were converted to bcm at a conversion factor of 1.11 as advised by BP.
[25] The IEA figures presented are OECD Europe total coal demand, adjusted by BEIS to reflect European import demand for thermal coal.

Annex C – Comparison of prices with key external projections

The tables below compare price projections of different institutions focusing on those that present a range of price assumptions and where information is publically available. Clearly there is a wide range of views driven by alternative views on states of the world and underlying assumptions. What is clear, however, is that in general BEIS low assumptions fall within the range of views presented by other institutions. However, relative to others, BEIS's central and high oil price assumptions are lower than others as the fundamental underlying assumption is that the supply side will be responsive to high prices in the long run and drive prices towards marginal costs of extraction.

Oil

Prices in 2017 $/bbl				
	BEIS Low	**IEA 450 Scenario**	**EIA low oil price**	
2020	37	76	30	
2030	55	88	37	
2040	55	81	44	
	BEIS Central	**IEA New Policies**	**EIA Reference**	**OPEC Reference***
2020	57	82	76	62
2030	80	115	97	
2040	80	128	112	95
* OPEC refers to its future prices as to "working assumptions" not representing price projections				
	BEIS High	**IEA Current Policies**	**EIA high oil price**	
2020	78	85	156	
2030	120	132	127	
2040	120	151	146	

IEA publication: WEO 2016
EIA publication: IEO 2016
OPEC publication: WOO 2016.

Gas

Prices in 2017 p/therm					
	BEIS Low	**IEA 450 Scenario**			
2020	34	53			
2030	39	72			
2040	39	76			
	BEIS Central	**IEA New Policies Scenario**	**External Projections***		
2020	43	54	30	73	50
2030	67	79	67	149	68
2040	67	88	-	168	75
	BEIS High	**IEA Current Policies Scenario**			
2020	62	56			
2030	83	85			
2040	83	99			

IEA: WEO 2016
*Aurora (Jan 2017) ,Wood Mackenzie (Dec 2016) and IHS (April 2017)

Coal

Prices in 2017 $/tonne					
	BEIS Low	**IEA 450 Scenario**	**External projections***		
2020	43	60	54	61	
2030	61	59	35	66	
2040	61	53	-	61	
	BEIS Central	**IEA New Policies Scenario**	**External Projections***		
2020	65	65	57	62	65
2030	88	77	68	76	77
2040	88	80	-	76	-
	BEIS High	**IEA Current Policies Scenario**	**External projections***		
2020	-	67	61	72	
2030	115	83	113	97	
2040	115	91		108	

* Aurora (Jan 2017), Wood Mackenzie (Dec 2016) and I.H.S. (Jul 2016)

Department for Business, Energy & Industrial Strategy
1 Victoria Place, SW1H 0ET
www.gov.uk/beis