The Implications of Fracking in UK Gas Import Substitution

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FINAL REPORT

by

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Executive Summary

This report estimates the scale of onshore shale gas production that would be required to replace 50% and 100% of gas imported to the UK in the period of 2021-2035 inclusive. It uses the most up-to-date estimates of this UK gas requirements from the Department for Business, Energy & Industrial Strategy and from National Grid.

Shale gas has not been exploited in the UK at commercial scale. Significant uncertainty remains on how the industry would work in practice, given a UK geological, regulatory and industrial context that is very different from the US where shale gas (and shale oil) is produced at scale.

We use a range of academic, government and industry reports to assess the likely productivity per UK shale well under optimistic, central and low scenarios, and then present estimates of the numbers of shale wells that would need to be drilled, and well-pads constructed, to meet UK import requirements.

Using a central estimate of well productivity from a report by Ricardo AEA in 2014 we estimate that 6,100 wells would be required to replace 50% of UK gas imports over the 2021-2035 period. This equates to 1.1 wells drilled each day.

Assuming six well bores for each shale pad (a figure higher than in the current US industry) results in an estimate of 3,560 hectares of land-take over the period, with potentially significant land requirements additional to this for pipelines, roads and other infrastructure.

It should be noted that this report only looks at shale gas. It does not, for example, look at possible production of unconventional oil, such as that found beneath the Weald in South East England, or other unconventional fossil fuel exploitation (e.g. coal bed methane).

1 Introduction

1.1 Objectives and Method

This report illustrates the potential impact of replacing imported natural gas with gas sourced from onshore fracking operations in the UK. We estimate the numbers of pads and wells required.

In order to frame the results, we present three scenarios for fracking development;

- A Low scenario, where the industry faces significant geological and other constraints and productivity is low
- A Central scenario which represents a ‘midpoint’ of productivity per well
- An Optimistic scenario, where per-well lifetime output is similar to the best experienced in US shale plays.

For each case we estimate industry scale required for;

- Adequate supply to replace 50% of (estimated) UK gas imports for the period 2021-2035 (inclusive)
- Adequate supply to replace 100% of (estimated) UK gas imports for the same period.

Clearly, with very limited instances of commercial-scale fracking outside North America, this analysis can only be indicative, with results reliant on a number of unknowns including the most appropriate technical approaches to fracking in the UK, levels of investment cost, and issues around geology, access and gas distribution. Moreover, we do not comment in detail on important issues including;

- The climate implications of switching from imported piped gas or LNG to fracked gas
- The relative competitiveness, in the short or longer run, of fracked gas vis-à-vis other fossil fuels (or indeed renewable or nuclear alternatives in applications where they are substitutable)

This report draws upon a variety of sources to present an up-to-date picture of the potential contribution and impact of UK gas fracking. Data are, however, extremely scarce and we default (as have previous EU and UK oriented reports) to the only detailed data available, which is typically from US shale gas plays.

Readers should note that the 'easier' geology in US shale areas and the existence of a mature and mobile shale production industry mean that, for the UK, gas production is likely to be lower and investment / production costs higher than in the US. Our estimates of UK overall and imported gas needs are based on data recently released by the UK Government Department for Business, Energy and Industrial Strategy (BEIS), and on National Grid Future Energy Scenarios for 2017.

1.2 The Nature of Fracking Operations & Concepts

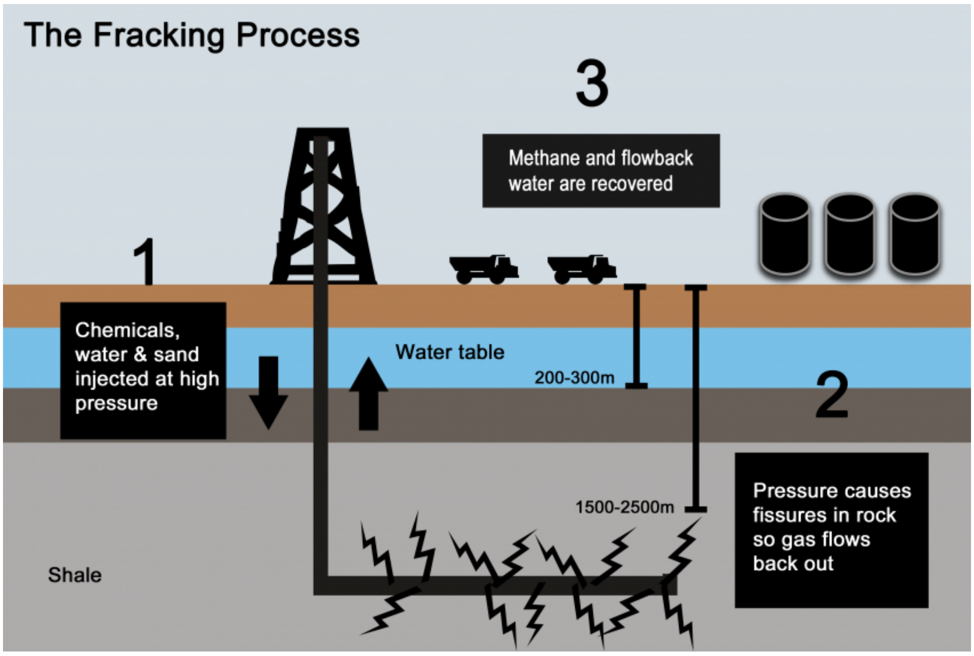
The process of hydraulic fracturing – or fracking – relates to the exploitation of gas or oil reserves that are suspended in porous rocks, and hence impossible to extract using traditional drilling methods. Instead of merely drilling vertically, fracking typically (but not always) requires vertical bores to be drilled then extended horizontally along underground shale seams, with a mix of water and chemicals then injected into the holes at very high pressure to widen existing fractures in the rock, or create new ones. This releases their trapped hydrocarbons, which then come up the well to the surface. Shale rock formations – or **plays** – can extend many kilometres horizontally, although in the UK the geology of such layers is more complex than that of plays in the continental US, meaning extraction may be more challenging.

Each shale gas rig sits atop its own bore, or **well** for the initial drilling period. Rigs are placed upon a stable drilling **pad**. Depending on a variety of factors, pads may house one vertical well, or several.

In the US, production so far has comprised the exploitation of single horizontal layer of shale by each well. Some industry commentators suggest that as the UK has (some) thicker shale deposits, it may be possible to drill more than one horizontal layer in a well. This process, known as the drilling of multiple **laterals**, would enable more gas to be exploited per well. So far however the technical viability and any productivity improvement associated with multiple laterals is unknown.

Unlike 'traditional' oil and gas wells, which can be productive for decades, shale rigs wells are typically productive for only a short period. In the US, the vast majority of hydrocarbons are extracted within the first four years of well production[1]. Shale is effectively then a peripatetic industry, with rigs regularly moving both small distances and large, within and between plays, as individual wells become exhausted. The total amount of gas that is recoverable from a single well is called the Estimated Ultimate Recovery (**EUR**), measured in billions of cubic feet (bcf) or millions of cubic metres (MCM, or BCM for billions of cubic metres).

Figure 1 How Fracking Works



Source: Energy & Climate Intelligence Unit www.eciu.net

[1] See https://www.nature.com/articles/494307a; and https://www.oxfordenergy.org/wpcms/wp-content/uploads/2016/11/Unravelling-the-US-Shale-Productivity-Gains-WPM-69.pdf

1.3 Report Structure

The following Section of the report presents our key data sources, conceptual approach and assumptions in more detail, including our estimate of the gas import requirements of the UK in the period 2021-2035, and our estimate of fracked well productivity. Section Three then presents the implications of a large-scale switch to fracked gas to replace 50% and 100% of imported gas, in terms of well numbers and land impacts. Section Four concludes.

2 Conceptual Approach, Data Sources and Assumptions

2.1 Conceptual Approach

Estimating the likely contribution of unconventional fuels to the UK energy mix (oil, gas or coal bed methane for example) is a difficult task, given the uncertainties over its cost competitiveness (with other fossil fuels, renewables and nuclear); social and environmental impacts; and geological, technical and logistical challenges. Here we abstract from the majority of these considerations to ask a relatively straightforward question: how many unconventional gas (UG) wells would be required to replace 50% and 100% imported gas in the UK energy mix for the fifteen years 2021-2035?

Further simplification is achieved by treating this period as a single block of time, rather than estimating annual contribution and resultant industrial activity. Annual forecasts of UK gas demand are of course available (see Appendix 1), and such an estimate is feasible, but would require significantly more complex modelling of (unknown) industry growth and well-depletion rates.

In this report, we estimate the cumulative demand for gas in the UK over our time period, and the extent to which this is likely to be provided by UK conventional gas, both onshore and offshore, and potentially ‘green’ gas to, by remainder, arrive at an estimate of the overall import requirement. This requirement is then compared with our best estimate of UG individual well productivity in terms of ultimately recoverable energy resources. Then, by division, we estimate the number of wells required to cover UK gas requirements (replacing 50% and 100% of imports over the period).

This broad-brush approach glosses over a number of complexities, not least the time-profile of demand and supply. However, given the very short-term nature of fracking production at individual well scale – the vast majority of gas is extracted in the first 4 years – production shortfalls or ‘overhangs’ at the beginning and end of the period are not significant.

Additionally, the likely (or at least technically feasible) continued production and contribution of North Sea gas into the late 2020s at some scale means any fracking industry would have time to grow to fill any supply gap (albeit perhaps with cost-competitiveness and public acceptance still challenging barriers[2]).

2.2 Data Sources

Our estimate of the demand for gas from the UK through the forecast period relies upon two key documents;

Updated energy and emissions projections 2017, Department for Business, Energy & Industrial Strategy (January 2018)[3] – Specifically we use the **Reference Scenario** of Annex E - Primary Energy Demand for our estimate of UK natural gas demand.

Future Energy Scenarios 2017, Natural Grid (July 2017)[4] – where we estimate the supply of UK conventional and green gas production. We use the **Consumer Power scenario** as;

- this is close to the overall estimate of UK Gas demand in the BEIS reference scenario,
- it assumes substantial production of fracked gas in the UK mix and
- it is one of two scenarios for which National Grid provide detailed data.

Note however that the Consumer Power scenario does not meet the UK's legally-binding climate targets.

A number of reports covering the UK, EU and US have informed this study, including;

Assumptions to the Annual Energy Outlook 2016 U.S. Energy Information Administration (January 2017)[5]

[2] Ricardo AEA; https://www.nottingham.ac.uk/news/pressreleases/2016/october/support-for-fracking-is-at-an-all-time-low-says-new-survey.aspx
[3] https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2017
[4] http://fes.nationalgrid.com/fes-document/
[5] https://www.eia.gov/outlooks/aeo/assumptions/pdf/0554(2016).pdf

Unconventional Gas: Potential Energy Market Impacts in the European Union European Commission Joint Research Centre Institute for Energy and Transport (2012)[6]

Unconventional Gas in England: Description of infrastructure and future scenarios Ricardo AEA (February 2014)[7] which itself incorporates earlier work from Manchester University's Tyndall Centre[8] and by the EU JRF report above

Getting Shale Gas Working Infrastructure for Business 2013#6 Institute of Directors/Cuadrilla (2013)[9]

Socio-economic Impact of Unconventional Gas in Wales Regeneris, Cardiff University & AMEC (July 2015)[10]

Developing Shale Gas and Maintaining the Beauty of the British Countryside UKOOG (January 2017)[11]

Other national and local government reports and academic sources have been used for reference and are noted in the text as appropriate. We would reinforce here that UG reports overall give a very partial picture of the likely development and productivity of UK shale plays, and a large amount of (often US sourced) information on productivity, cost and depletion rates is common amongst them.

2.3 Assumptions

We draw our assumptions from across the range of reports published on shale in the UK and EU in recent years, weighting reports, statistics and papers sponsored by governments more heavily.

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[6] https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/unconventional-gas-europe-potential-energy-market-impacts

[7] http://vibe.cira.colostate.edu/ogec/docs/Primers/ED58661-scenarios030214v14.pdf

[8] www.mace.manchester.ac.uk/media/eps/schoolofmechanicalaerospaceandcivilengineering/newsandevents/news/research/pdfs2011/shale-gas-threat-report.pdf

[9] https://www.igasplc.com/media/3067/iod-getting-shale-gas-working-main-report.pdf

[10] Unavailable online at time of writing

[11] http://www.ukoog.org.uk/about-ukoog/press-releases/197-ukoog-publishes-study-showing-limited-impact-of-shale-gas-development-on-countryside

Note that our estimate of wells per pad, whilst lower than the estimate by IoD, is still well in excess of US averages which, albeit increasing, are still low: few pads have more than 5 wells[12] and multiple laterally-drilled wells (an integral part of the IoD analysis) are not typically used in the US. Whilst multiple laterals may be more geologically feasible or technically attractive in the UK, this has not yet been proven and even the very thick (lower) Bowland shale deposits may not be easily exploitable in this way[13]. Our EUR productivity estimates are based on extensive European Union analysis, and range from 0.021 – 0.085 billion cubic metres for US wells.

Table 1 Summary of assumptions

Item	Assumption		Source
UK Gas Demand 2021-35 (bcm)		990	BEIS Energy & emissions projections 2017
Import requirement 2021-35 (bcm)		695	National Grid FES Consumer Power scenario
EUR per well (BCM)	Optimistic:	0.085	EU JRF estimates quoted in Ricardo AEA (2014) p 61.
	Central:	0.057	
	Low:	0.021	
Wells (inc. laterals) per pad*		6	Regeneris (2015); (UKOOG 2017). This is higher than the currently US average number of wells per pad.
Hectares per pad		3.5	Derived from a number of sources[14]. Includes direct pad size plus additional habitat loss, and loss of utility from areas surrounding pad[15]. *Note that total land impact per pad including roads, pipelines etc. may be as high as 15-20 Ha[16] but we do not model this here.*

*note we assume here that boring multiple laterals will have no impact on productivity per bore.

[12] See https://link.springer.com/article/10.1007/s00267-012-9841-6; http://wvsoro.org/multiple-horizontal-wells-centralized-well-pads/; http://www.sciencedirect.com/science/article/pii/S0301479714001911 for example

[13] Ricardo-AEA (2014) p62; https://www.theguardian.com/environment/2017/aug/17/uk-fracking-may-produce-less-fuel-than-claimed-says-geologist

[14] https://www.elsevier.com/connect/fracking-what-does-it-mean-for-local-people; http://ec.europa.eu/environment/integration/research/newsalert/pdf/overview_of_environmental_impacts_of_shale_gas_and_oil_398na1_en.pdf. Note multi-well pads reduce the

[15] Note multi well pads of the sort modelled here reduce the land take per well, but each pad will have a greater footprint, for example creating more waste than a single well pad; http://www.sciencedirect.com/science/article/pii/S0301479714001911

[16] https://www.scientific.net/AMR.734-737.251

3 The Implications of Fracked Gas in UK Gas Import Substitution

3.1 The possible scale of UK Shale Gas Production

Adopting the assumptions detailed in Section 2 enables our estimate of the number of wells required to replace 50% and 100% of UK imported gas between 2021 and 2035 – and divided into low, central and optimistic scenarios[17].

Our Central estimate is that the replacement of 50% of UK gas imports would require the drilling of around 6,100 shale wells during the period 2021 to 2035 – this equates to drilling and fracking around 1.1 new wells each day.

Table 2 Well Requirements for UK Shale Production

	Well productivity (BCM)	50% UK Imports	100% UK Imports
Low	0.021	16,550	33,100
Central	0.057	6,100	12,190
Optimistic	0.085	4,090	8,180

The Optimistic scenario suggests that more productive wells could cut this scale estimate to 4,090 and 8,180 wells to replace 50% and 100% of imports respectively. However, if geological and other issues reduce well productivity to the 'Low' estimates in the 2014 Ricardo-AEA report, around 16,550 wells will be required to completely replace 50% of imports – this equates to drilling and fracking over 3 new wells every day.

[17] Note in all tables numbers may not sum due to individual rounding.

The number of shale pads (and hence land-take) associated with these wells is open to debate, with (even relatively recently) pads in the USA having a low number of wells, but with UKOOG and others suggesting that UK geology may enable a higher number of wells per pad. We present the case of 6 well-pads as the most likely scenario. Here then, replacing 50% of UK gas imports would, in our Central scenario, require 3,560 Ha of (direct) land take, ranging from as low as 2,380 Ha in the Optimistic case and 9,650 Ha in the low-productivity scenario (Table 3).

Table 3 Land Requirements of Shale Production[18]

Productivity Scenario	Ha per pad	Pads	Total Ha (50%)	Total Ha (100%)
Low	3.5	2,760	9,650	19,310
Central	3.5	1,020	3,560	7,110
Optimistic	3.5	680	2,380	4,770

It is impossible to say for how long this land would be in use for – following shale exploitation it could potentially be remediated for other uses, with this dependent on the nature of local environmental impact. Sites in the US are associated with soil and water contamination that may have implications for other uses, but with UK environmental regulation very different to that in the US, the extent of such impacts here is unknown[19].

It is worth placing these implications in relation to existing UK gas supply activities. A typical LNG tanker can transport around 0.85bcm of gas. Thus in the central scenario (Table 2) 1.5 wells would produce over their circa 15-year lifetime a similar amount of gas as that in a single LNG tanker delivery[20]. Clearly then, for the most pessimistic scenario *four* wells would be required to replace one tanker delivery.

[18] Note the assumption that pads with more wells are physically larger
[19] See http://onlinelibrary.wiley.com/doi/10.1111/j.1745-6592.2007.00155.x/pdf
http://pubs.acs.org/doi/abs/10.1021/es402165b - this stringency of course implies higher cost and lower viability for UK shale compared to the US.
[20] http://extension.psu.edu/natural-resources/natural-gas/news/2012/02/understanding-the-role-of-liquefied-natural-gas-part-1

4 Conclusion

This report has examined the scale of fracked-gas development that would be required to half-replace and completely replace UK natural gas imports in the period 2021-2035, using the latest available energy demand/supply forecasts from UK Government and other sources, and the best available information from US commercial development.

Our three scenarios for productivity per well – entitled Low, Central and Optimistic – do no differ greatly in their aggregate implications from previous estimates undertaken by the Tyndall Climate Centre in 2011; for the EU in 2012; then by Ricardo-AEA for the UK in 2014; and by Regeneris (with ourselves) for Wales in 2015. This is unsurprising as there is considerable overlap and circularity in the data that underpin these reports. The exception is the report by the Institute of Directors with Cuadrilla (2013) that is far more optimistic about the technical efficiencies involved in future UK shale production, and thus reports far lower physical scale and impact for the same amount of gas production.

Our central scenario then suggests around 6,100 shale wells would need to be drilled to replace half of UK gas imports in the period to 2035. In this scenario, with a reasonably optimistic assumption of 6 wells per pad (hence 1,020 pads), this implies the construction (and eventual dismantling) of one shale gas pad roughly every 5 days over the fifteen years. Our best estimate is that this would involve around 3,560 Ha of land-take.

What is notable in the period since 2010 is that there has been no commercial exploitation of shale gas in the UK despite a very favourable policy environment, including substantial tax incentives[21]. Shale gas is currently not economically viable, certainly within a market that allows purchase of gas from a variety of piped and tanker sources, and where significant drops in the per-MWh cost of renewables (notably onshore and offshore wind and solar)[22] together with climate levies are placing an effective cap on the maximum cost of fossil fuels specifically for electricity generation. It is notable that during this time, coal generation has diminished rapidly in the UK energy supply mix, reducing the climate rationale for a switch to shale for electricity production to negligible (or beyond). Add to this the

[21] https://www.mayerbrown.com/Shale-Gas-The-UK-Announces-Tax-Incentives-05-09-2013/
[22] Most recently and notably https://www.bloomberg.com/news/articles/2017-09-11/u-k-offshore-wind-costs-fall-to-record-in-latest-auction

significant reluctance for communities across the UK to host shale production (or even exploration) and the investment climate for fracking remains problematic.

In the absence of big political or (positive) economic shocks, this lack of viability and attractiveness is likely to persist for a number of years. There is no indication that established gas exporters – and potential new ones from North America – will reduce supply of alternative, relatively cheaper gases, and National Grid and others are investing in ways that will make renewables comparatively even more competitive in the UK electricity mix[23].

Our scenarios thus try to describe the nature of *potential* shale production in the UK best, but they all may be rather improbable in terms of their assumed priors – certainly in application to the quoted timeframe. At time of writing, and on current trends there is no evidence that fracked gas can be brought to market at sufficiently low cost, and sufficiently great volume to make any significant profit, or to make any difference to the UK energy security position (let alone the UK gas price). In the absence of significant change to contextual factors, the UK onshore gas reserves will remain purely of geological interest.

[23] See for example https://www.greentechmedia.com/articles/read/uks-national-grid-goes-big-into-energy-storage-with-201mw-of-fast-acting-ba and http://www.newsweek.com/uk-grid-artificial-intelligence-energy-supply-supply-and-demand-550148

Appendix 1: Estimation of UK Gas Import Requirements

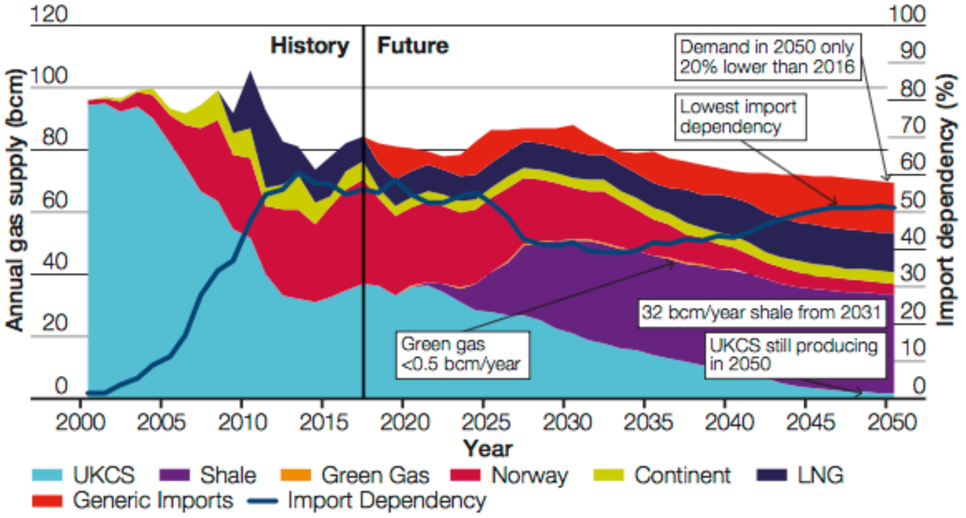
Item	Value	Source & Notes
a. Total UK Primary energy demand 2021 – 2035	2,770 Megatonnes of Oil equivalent (Mtoe) equal to 3,075 Billion Cubic Metres of Gas (BCF)	BEIS reference scenario. Annual energy consumption in the UK is around 200 Mtoe
b. Total UK Natural Gas demand 2021 – 2035	890 Mtoe / 985 BCM	BEIS reference scenario 2017. Annex E
c. Proportion of Natural Gas imported 2021 - 2035	70%	National Grid Consumer Power Scenario. The weighted average of annual import propensities for each year (from Norway, LNG, Continent & Generic Imports) under assumption of UK shale development
d. UK Gas Import requirements 2021 - 2035	695 BCM	b. x c.

National Grid Future Energy Scenarios 2017 (Consumer Power)															BCM	
Year	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**Cumulative**
UKCS	36	35	31	28	28	27	27	25	22	21	19	18	16	16	14	364
Shale	1	2	4	9	13	17	23	26	28	30	32	32	32	32	32	312
Green gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Norway	26	25	24	24	24	24	21	20	18	17	16	17	15	13	12	295
Continent	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	53
LNG	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	123
Generic imports	4	4	7	10	10	7	4	5	6	8	6	4	5	6	10	97
Demand	80	78	79	83	86	86	87	87	87	88	85	82	80	79	80	1247
Import dependency	53%	52%	55%	55%	53%	49%	43%	42%	41%	42%	40%	39%	39%	40%	42%	
Non-shale UK production	*37*	*35*	*31*	*29*	*28*	*27*	*27*	*25*	*23*	*21*	*19*	*18*	*17*	*16*	*14*	*368*
UK Import requirement (no shale)	43	43	47	54	58	59	60	62	64	67	66	64	63	63	65	*880*
Import dependency (no shale)	*54%*	*55%*	*60%*	*65%*	*67%*	*68%*	*69%*	*71%*	*74%*	*76%*	*77%*	*78%*	*79%*	*80%*	*82%*	*71%*

BEIS Projection of Primary Energy Demand by source 2017 (Reference Scenario)															Mtoe	
	2021	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**Cumulative**
Electricity net imports[2]	3	4	5	7	7	7	7	6	6	7	7	6	6	5	4	86
Natural gas	63	61	60	60	58	58	59	59	59	60	58	58	58	58	59	889
Nuclear	15	14	12	9	10	13	13	16	18	16	18	21	22	25	28	249
Oil	71	71	71	71	70	70	70	70	70	70	70	70	70	70	70	1052
Renewables & waste[3]	27	27	28	28	28	28	27	26	27	27	27	28	28	28	29	413
Solids[4]	9	7	7	7	7	5	5	5	5	5	5	4	4	4	4	83
Total primary energy demand	**187**	**184**	**182**	**181**	**179**	**181**	**181**	**182**	**186**	**184**	**184**	**187**	**187**	**191**	**193**	2772
Natural gas requirement	63	61	60	60	58	58	59	59	59	60	58	58	58	58	59	889
Import dependency (no shale)	*34*	*34*	*36*	*39*	*39*	*40*	*41*	*42*	*44*	*45*	*45*	*45*	*46*	*47*	*48*	625
															BCM	**694**

Note: numbers in tables may not add due to independent rounding

UK Gas Supply 2000-2050 - Consumer Power Scenario (FES Fig 4.16)



Source: National Grid