Annex A12.04 Compressor Supporting Information December 2019

As a part of the NGGT Business Plan Submission

nationalgrid

Introduction

Our business plan outlines the investments we have assessed as required in RIIO-2 to deliver the network capability required by customers and stakeholders. In Chapter 12 of our business plan we show the network capability delivered by our planned investments and how this compares to the range of potential stakeholder requirements under the four FES scenarios, on which the ENA common scenario was built to ensure the decisions we make now, will be fit for purpose under all scenarios.

This level of capability is delivered through a combination of our asset health programme, our compressor programme and our approach to asset management including decisions on decommissioning of redundant assets. We must also invest to protect our Critical National Infrastructure (CNI) assets from physical and cyber security threats in accordance with UK Government and industry best practice requirements.

Investments in these areas can be found in the following chapters of our business plan:

- Chapter 14 for asset health investments and our approach to asset management and system operation
- Chapter 15 for cyber and physical threats investments
- Chapter 16 for specific compressor investment proposals related to the impact of environmental legislation and in line with our strategy as outlined in our Compressor Emission Compliance Strategy (CECS – Annex A16.05). Where we are making proposals to replace compressors these are supported by site specific investment decision packs comprising of Engineering Justification Papers (EJPs) and Cost Benefit Analysis[1] (CBA).

We recognise that there are material costs for certain compressor sites, not captured in the site-specific investment decision packs which are referenced from Chapter 16. These costs (e.g. for Asset Health and Cyber) are covered in the relevant chapters (as above), in the supporting Engineering Justification Papers (EJPs) and other annexes referenced from these chapters. This annex explains why these investments, to retain capability at these compressor sites, are in the interest of consumers in terms of reliability and resilience in providing appropriate levels of network capability and in meeting our obligations.

Parts of the analysis contained in this annex, is based around network investment costs compared to the costs of managing constraints or entering into commercial contracts in the absence of these investments. Whilst the analysis in the annex has focussed on the costs of constraint management and contractual options, it should be noted that both these options would result in disruption to gas flows onto or off the network. This could have several impacts, including to wholesale gas prices. If the disruption impacts power generators there would also be consequential impacts on the electricity industry. More information on impacts of insufficient levels of network capability can be found in Chapter 12 and Annex 12.01.

[1] These are referenced from both Chapter 12 and Chapter 16

Structure of this Annex

This annex is divided into 5 sections each covering a specific compressor(s), this is summarised in the table below. Given that a number of compressor sites working together provide the overall network capability required, it is important to describe the investments in logical, geographical groups to better understand why we are investing and how this forms the optimal solution across the network. These groups map to the compressor narrative tables in the Network Capability Chapter (Chapter 12) of our business plan, as shown in the table below.

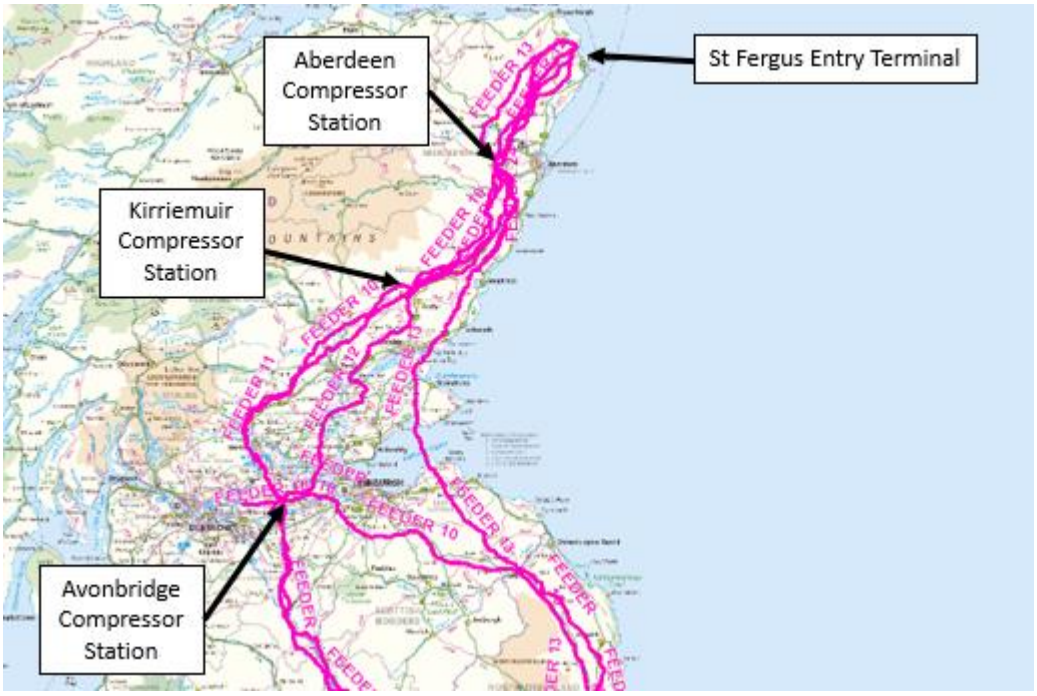
Section	Compressors	Link to Network Capability Chapter in the business plan
A	Avonbridge, Kirriemuir and Aberdeen	Figure 12.08 & Table 12.09
B	Bishop Auckland, Nether Kellet and Carnforth	Figure 12.08 & Table 12.09
C	Churchover, Felindre and Alrewas	Figure 12.10 & Table 12.11
D	Diss, Chelmsford, Cambridge	Figure 12.14 & Table 12.15
E	Lockerley	Figure 12.14 & Table 12.15

Section A - Avonbridge, Kirriemuir and Aberdeen

As described in FES, and as requested by our stakeholders, there is an ongoing requirement for compression in Scotland to support the transmission of gas from St Fergus in the North to the South through RIIO-2 and beyond. This provides a resilient capability to accept gas at the St Fergus entry terminal, where UKCS and Norwegian gas enters the NTS and is transported South along the West or East Coast of the country.

Aberdeen, Kirriemuir and Avonbridge are the primary, high utilisation compressor sites in Scotland operating in a chain from North to South, the location of these compressors is shown in Figure A1.

Figure A1: Location of the Aberdeen, Kirriemuir and Avonbridge compressor sites.

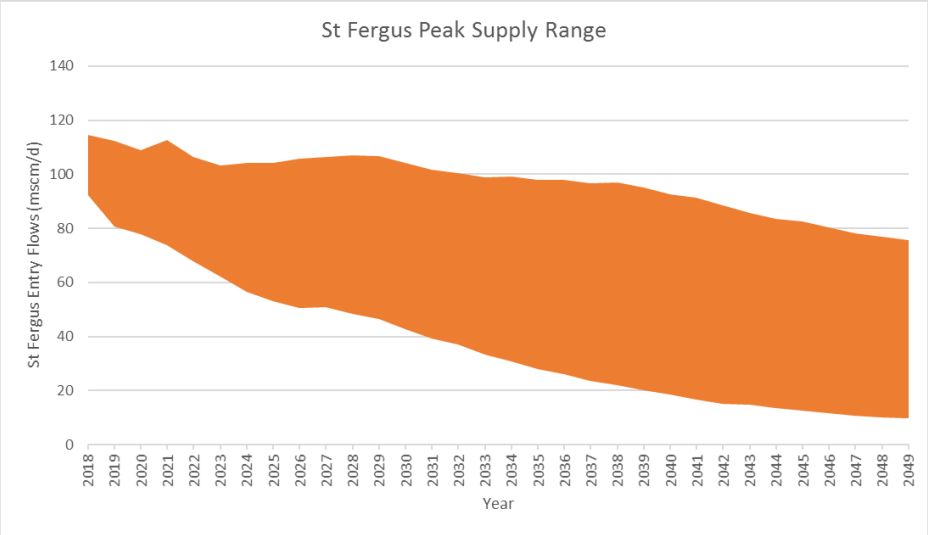


We will typically operate two out of these three primary sites when levels of supply at St Fergus significantly exceed levels of demand in Scotland, which can occur at any time of the year. The availability of the third site is particularly valuable in summer to facilitate planned site outages for essential maintenance, but also provides resilience due to unplanned outages on a year-round basis. This contributes to the spread of running hours across the three sites evident in Figure A2. Supplies at St Fergus increased significantly in 2016, leading to a corresponding increase in run hours across all three sites. In 2018/19, these were the three highest utilisation sites on the NTS. The forecast range of St Fergus flows during RIIO-2 are shown in Figure A3.

Figure A2: Compressor Station Running Hours

	14/15	15/16	16/17	17/18	18/19
Aberdeen	1,948	2,838	11,141	8,589	5,014
Avonbridge	1,602	3,836	9,935	10,939	6,410
Kirriemuir	1,688	5,400	1,532	1,776	3,165
Total	**5,238**	**12,074**	**22,608**	**21,304**	**14,589**

Figure A3: FES forecasts for St. Fergus flows



As well as providing network entry capability, compression is also required in Scotland to ensure that we deliver our pressure obligations to the Scotland distribution network and deliver compliance with our 1 in 20 licence obligation. Avonbridge compressor site is essential in this regard due to the flexibility it provides at low flow rates at times of low supplies from St. Fergus and its proximity to key offtakes such as Bathgate, which have a high assured offtake pressure obligation.

Aberdeen consists of three emission compliant gas units and provides the highest levels of entry capability at St Fergus when operating with Avonbridge or Kirriemuir. As the closest compressor site to St Fergus, Aberdeen provides the necessary quick response to short term changes in supply levels and provides flexibility to move gas towards the East or the West Coast of Scotland.

Aberdeen plays a critical role in controlling gas flows in different proportions across all of the pipelines in Scotland, and further South via the East and West Coast Transmission routes. This provides a resilient solution to incidents or threats on specific pipelines in moving gas away from St Fergus towards demand further South.

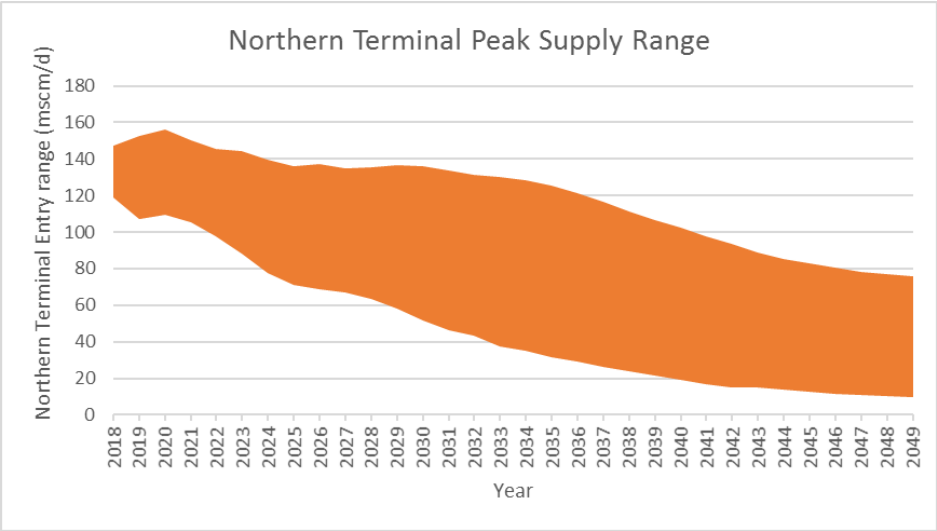
Kirriemuir consists of three Avon units which are non-compliant with the MCPD, together with one compliant electric unit. We are currently proposing to decommission the three non-compliant units by 2030. In the meantime Kirriemuir provides essential entry capability resilience for Aberdeen.

Section B - Bishop Auckland, Nether Kellet and Carnforth

Executive Summary

In addition to the compressors in Scotland[2], Bishop Auckland and Carnforth/Nether Kellet[3] play a critical role to support bulk transmission of gas from St Fergus, Teesside and Easington terminals to the South, supporting delivery of our entry capacity obligations and network capability at St Fergus, Teesside and Easington. Our RIIO-2 plan includes closure of the compressor sites at Warrington and Moffat, therefore compression at Carnforth/Nether Kellet will be the only compressors on the West Coast transmission route on a 465 km section between the compressors at Avonbridge and Alrewas. On the East Coast transmission route Bishop Auckland is the only compressor site on the 360 km pipeline route between the Wooler and Hatton compressor stations. These stations will therefore continue to play a critical bulk transmission role whilst flows at the Northern gas terminals remains high. Figure B1 shows the FES 2018 range of potential supplies from the Northern gas terminals (St Fergus, Teesside and Easington).

Figure B1: Northern Terminal Peak Supply Range



In the future as UK Continental Shelf (UKCS) supplies decline, supplies at these terminals are forecast to reduce resulting in a requirement for bulk transmission from the South to the North to meet customers exit requirements and to meet our 1 in 20 licence obligation. The date at which this South to North capability is required, depends on which FES scenario is considered, but the range of dates is between 2025 and 2040. There is no FES scenario where bulk transmission from either the North to the South or vice versa is not required at some future date. Carnforth/Nether Kellet and Bishop Auckland are the sites best located on the network to compress gas towards the North and Scotland up the West and East Coast transmission routes respectively. Whilst this will require additional investment at the sites it would provide the capability to meet consumer demand and provide resilience on the network for planned and unplanned events. This capability will be vital to meeting our 1 in 20 licence obligation and meeting the gas needs of distribution connected consumers (including domestic consumers) in the future.

We have considered turn-down contracts could provide an alternate option to compression in order to meet our 1 in 20 licence obligation in Scotland. However, there is insufficient volume of transmission connected large load and this option would require contracting with Irish export demand or the Scottish GDN. Due to the difficulty in securing the required volumes and the likely cost of any

[2] Discussed in Section A
[3] For historic reasons compressors were built at Nether Kellet on a separate site adjacent to the existing Carnforth compressor station. In terms of delivery of capability on the network, these sites can be considered together and are hence referred to as Carnforth/Nether Kellet in this annex.

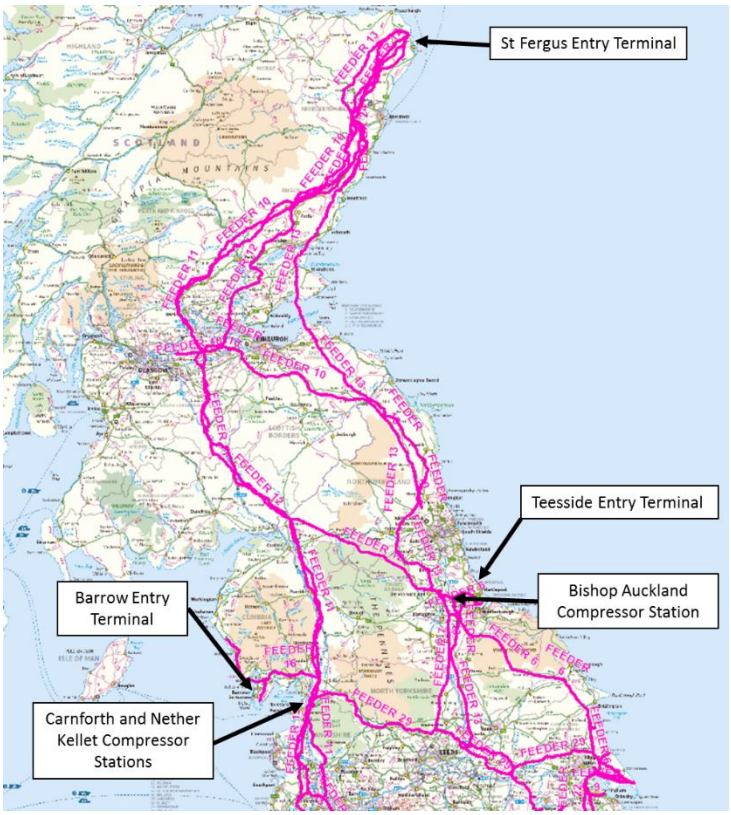
contracts we are proposing that the capability for these compressors to operate South to North remains the optimal solution to meet customer requirements.

These compressors also play a key role in managing pressures in the North West, to meet the requirements of storage operators and in facilitating entry flows at the Teesside gas reception terminal in the North East. The location of the compressors at Carnforth/Nether Kellet are also well placed to support any potential shale gas flows onto the network should Government policy change as they are located close to the most likely GB shale gas supplies in GB[4].

Background

Figure B2 shows the location of Carnforth/Nether Kellet on the West coast and Bishop Auckland on the East Coast.

Figure B2: Location of Carnforth, Nether Kellet and Bishop Auckland



Compression at Bishop Auckland and Carnforth/Nether Kellet is currently used for bulk transmission of gas entering in the North of the country at St Fergus, Teesside and Easington. They provide two alternate routes using either the West Coast chain of compressors (Carnforth/Nether Kellet and Alrewas) or the preferred East Coast route (Bishop Auckland and Hatton). They provide resilience to each other and under very high entry conditions in the North both routes will be used to move gas South to the high demand centres. Table **Table B3:**3 shows the run hours from each site for the last 5 years.

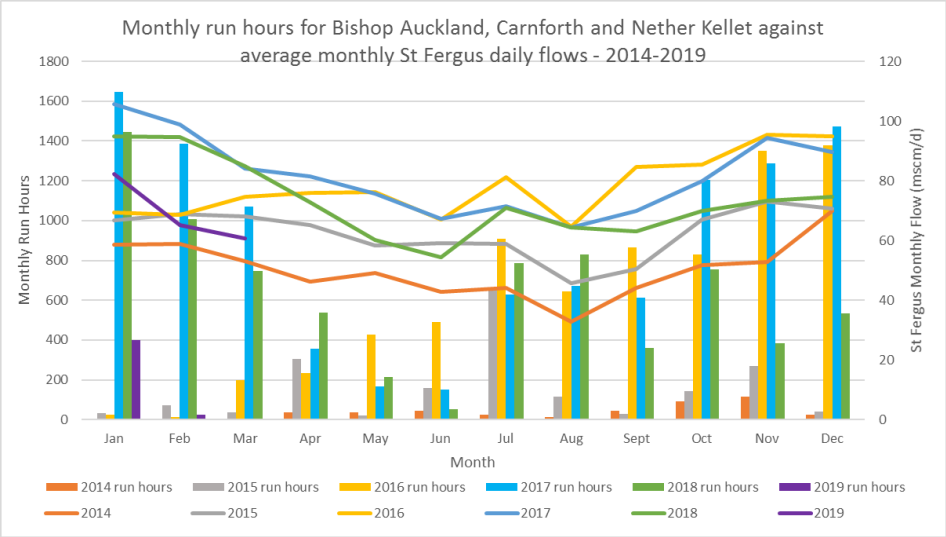
Table B3: Annual compressor run hours

	14/15	15/16	16/17	17/18	18/19
Carnforth	21	157	41	1	1835
Nether Kellet	275	782	5058	6006	3020
Bishop Auckland	273	1028	6132	3737	1835
Total	**569**	**1966**	**11232**	**9744**	**6690**

[4] The 2018 FES included shale gas in the consumer evolution scenario

Figure B4: compares the run hours from all three sites compared to the average entry flows at St Fergus, showing how the run hours for the three sites increase when entry flows through St Fergus are high.

Figure B4: Compressor run hours against monthly average St Fergus flows

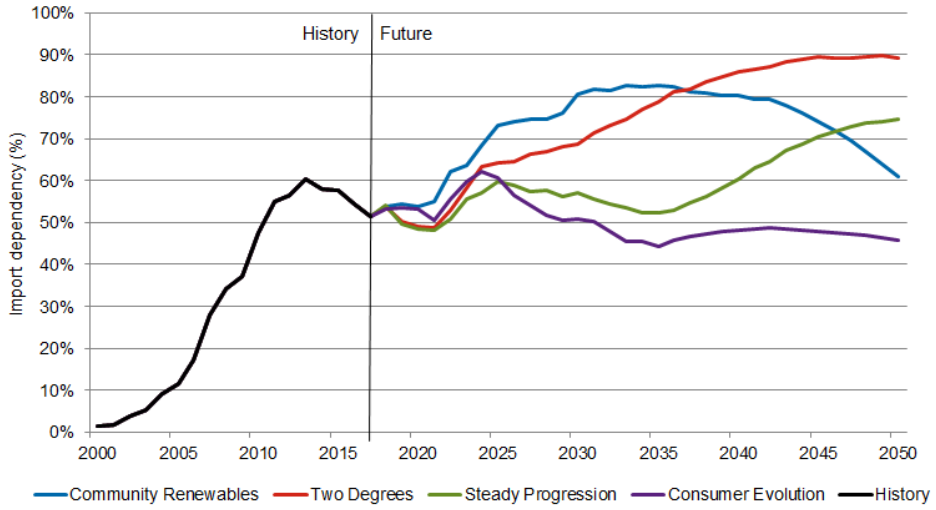


Changes in supply and demand

Over the next 20 years, supplies from the UKCS will continue to decline. The 2018 FES scenarios consider a range of possible sources to replace these, including development of other indigenous sources, higher imports (pipeline or LNG), shale gas, biomethane and bio-substitute natural gas (bioSNG). These supplies may connect to the NTS or to the distribution networks.

Three of the four FES scenarios show an increase in imported gas either from Continental Europe or LNG (Figure B5). The only scenario that does not see an increase in import dependency is Consumer Evolution. Gas demand is instead met by a significant increase in UK Shale.

Figure B5: Forecast imports under the range of FES scenarios



The scenario that has the greatest impact on North to South flows is the Two-Degree FES scenario with imports being prioritised through LNG. In this scenario, we would see LNG supplies double by

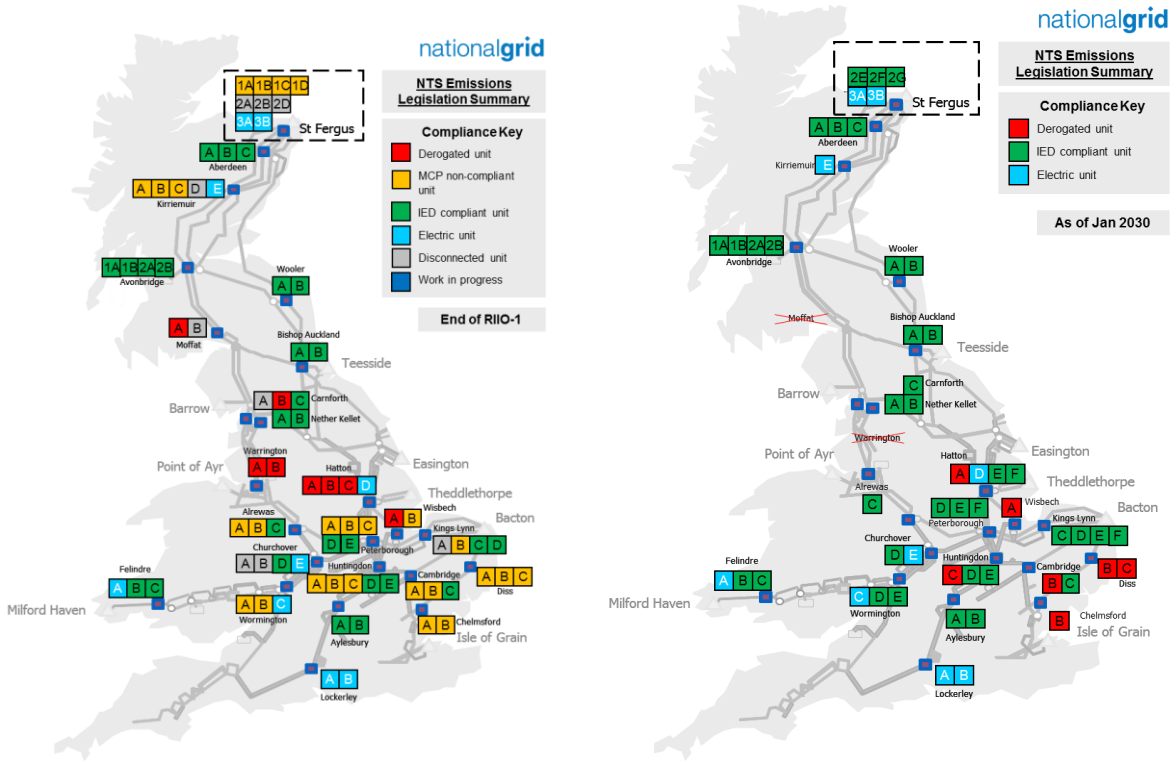
the end of RIIO-2 and could be five times the level seen today by 2030. This could result in a reduced requirement to move gas from North to South but create a new and significant requirement to move gas from the South to the North.

Meeting our entry capacity obligations at St Fergus, Teesside and Easington.

The forecast changes in supply patterns in FES 2018 are reflected in our compressor proposals out to 2030 (Figure B6), this shows that we are reducing the number of compressors on the network and limiting the running hours on others. With Moffat and Warrington closing on the West Coast transmission route Carnforth/Nether Kellet will be the only compressor site between Avonbridge and Alrewas, which are 465 km apart. This is similar on East Coast transmission route with Bishop Auckland the only site between Wooler and Hatton, which are 360 km apart.

Without compression over these distances large pressure drops would be created, reducing capability for bulk transfer of gas from North to South and accommodation of changing flow patterns on the network. With proposed reductions in the number of units at Carnforth and Alrewas the remaining units at Bishop Auckland, Carnforth and Nether Kellet will become more important for moving gas from the Scottish and Northern supply terminals South.

Figure B6: Proposed compression fleet at the end of RIIO-1 and the MCPD compliance date 1 January 2030



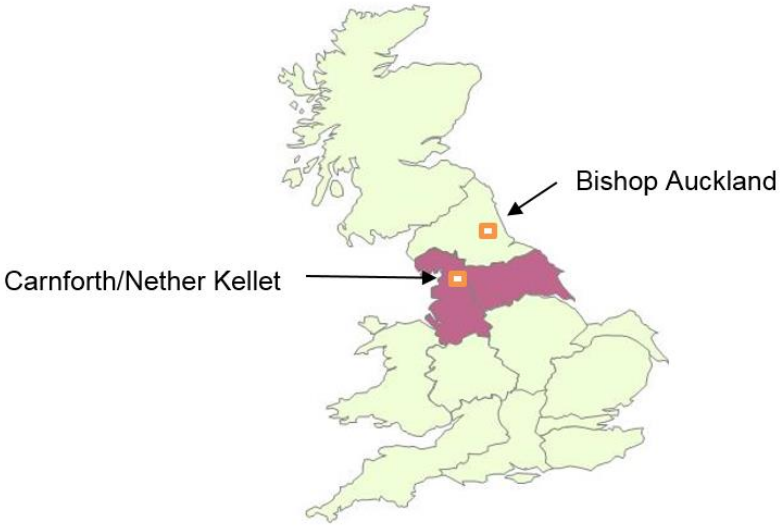
Meeting the needs of customers in the North West and North East

Compression at Carnforth/Nether Kellet supports the large number of storage sites in the North West by either supporting exit pressures or by managing entry pressures at these sites. From a wider network perspective, they allow within day flow changes from the storage sites to be accommodated.

In the North East, the location of the Bishop Auckland compressor is able to support high levels of entry flows, and within day changes to the flows from the Teesside entry terminal.

The future of shale in GB is currently uncertain following recent political announcements. Should policy change, the Bowland region (highlighted in Figure B7) represents the most likely location for future shale recovery in Great Britain. The position of Carnforth/Nether Kellet could make them ideal to facilitate shale gas flows, with the ability to compress gas South, East or North on the network[5].

Figure B7: Bowland region where shale gas production is most likely



Scottish 1 in 20 and meeting the needs of Scottish gas consumers

The forecast decline in UKCS supplies creates the need, at a future date, to move gas from the South to the North to ensure that we can continue to meet the 1 in 20 licence obligation in Scotland and supply gas to Scottish consumers. The date at which this South to North capability is required, depends on which FES scenario is considered, but the range of dates is between 2025 and ~2040. As an example, under the Two Degrees FES scenario, LNG imports double by the end of RIIO-2 and could be five times today's levels by 2030. It is this type of changing supply pattern that will create the need to transport gas South to North.

We have considered whether turn-down contracts could provide an alternate option, to compression to meet our 1 in 20 licence obligation in Scotland, however there is insufficient volume of Transmission connected large load and this option would require contracting with Irish export demand or demand within the Scottish GDN. [redacted] would make this solution potentially unachievable and if it were achievable, uneconomic. Due to the difficulty in securing the required volumes and the likely cost of any contracts we are currently proposing that the capability for these compressors to operate South to North remains the optimal solution to meet customer requirements.

Capability could be met with either Carnforth/Nether Kellet or Bishop Auckland but as the requirement for South to North flows increases the reversal of both sites is required to provide resilience and protect flows to Scottish consumers. The optimal timing for the investment at each site is yet to be confirmed. Removal of compression at either site would limit our options and ultimately result in a significantly more expensive long-term solution being required.

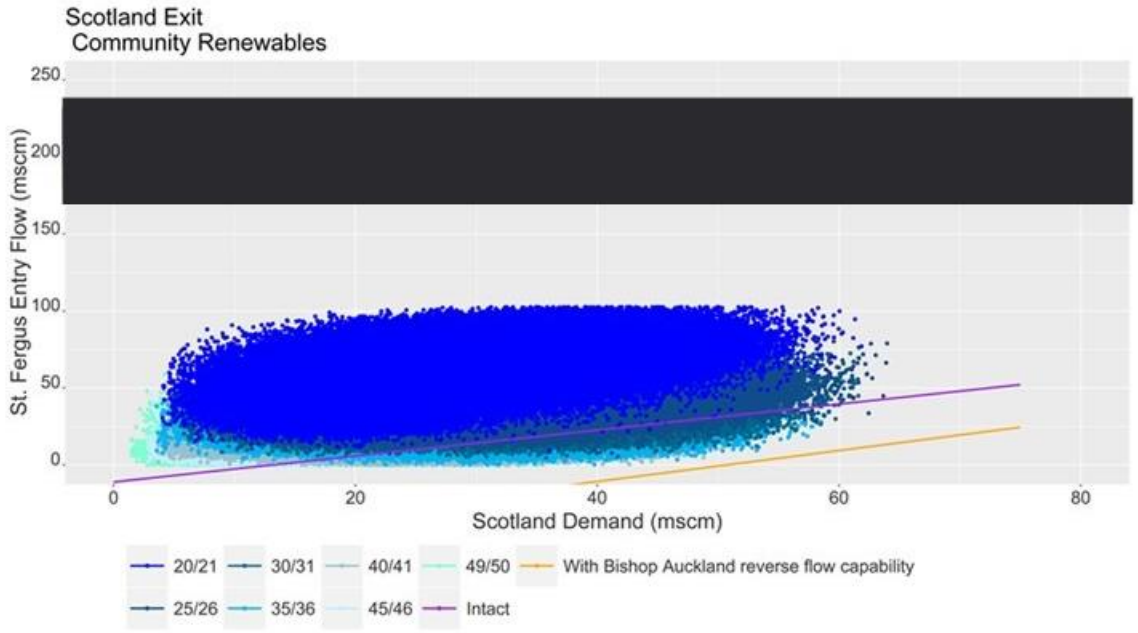
We have undertaken network analysis to determine the minimum St Fergus entry flows required to continue to meet Scottish demand (exit flows). This has been undertaken using scenarios with and without the ability of Bishop Auckland or Carnforth/Nether Kellet to compress gas North. The results

[5] Flows North would require some modification to the multi-junction for Carnforth/Nether Kellet

of this analysis are shown in Figures B8 to B11. These charts are subtlety different to others used elsewhere so we have included explanatory notes below:

- The dots[6] on the chart are based on customer requirements from the four FES scenarios.
- Each chart has two lines. The purple line shows our capability today and the orange line the capability with either Bishop Auckland or Carnforth/Nether Kellet compressing gas North. On these charts as capability increases the capability line moves down on the chart (this is different to other charts as the axis are different).
- The capability line shows the limitation in our ability to move gas North into Scotland. In occurrences with low St Fergus entry flows and high Scottish demand, it is the limitation of this capability which determines whether demand from Scottish consumers can be met. As a result, in these charts' constraints occur where the dots are **BELOW** the capability lines.
- The table at the top of the chart shows how the number of dots below the capability line translates into constraint days. It also shows how this changes with time under each of the four FES scenarios.

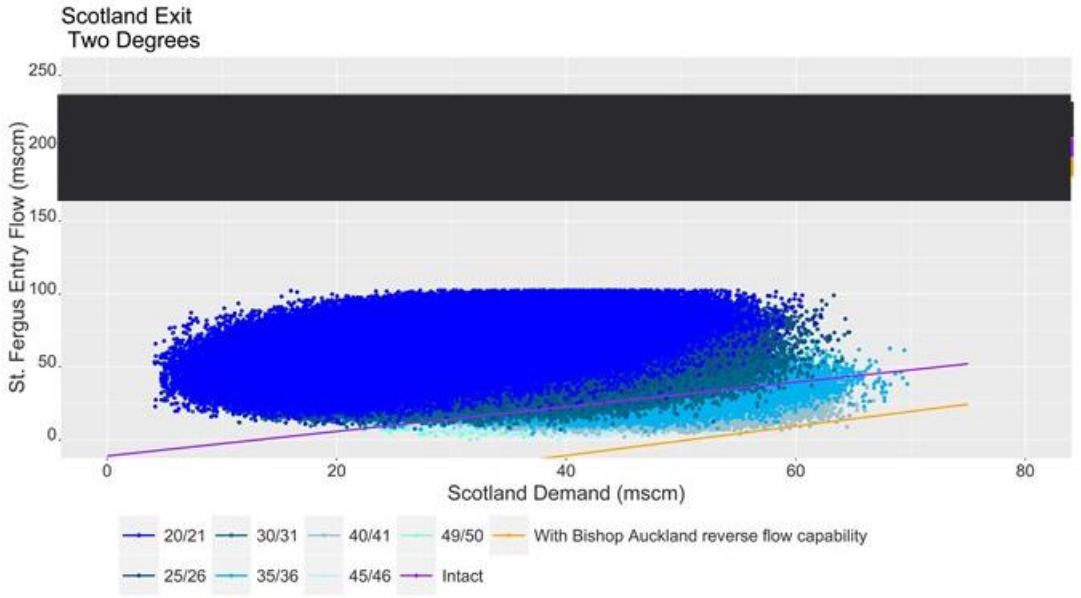
Figure B8: Scottish Exit Capability (Community Renewables scenario)



This scenario shows we would need reverse capability from 2025, the earliest date of all the four scenarios. The orange line shows that with either Bishop Auckland or Carnforth/Nether Kellet compressing North we can meet all supply and demand patterns beyond 2050.

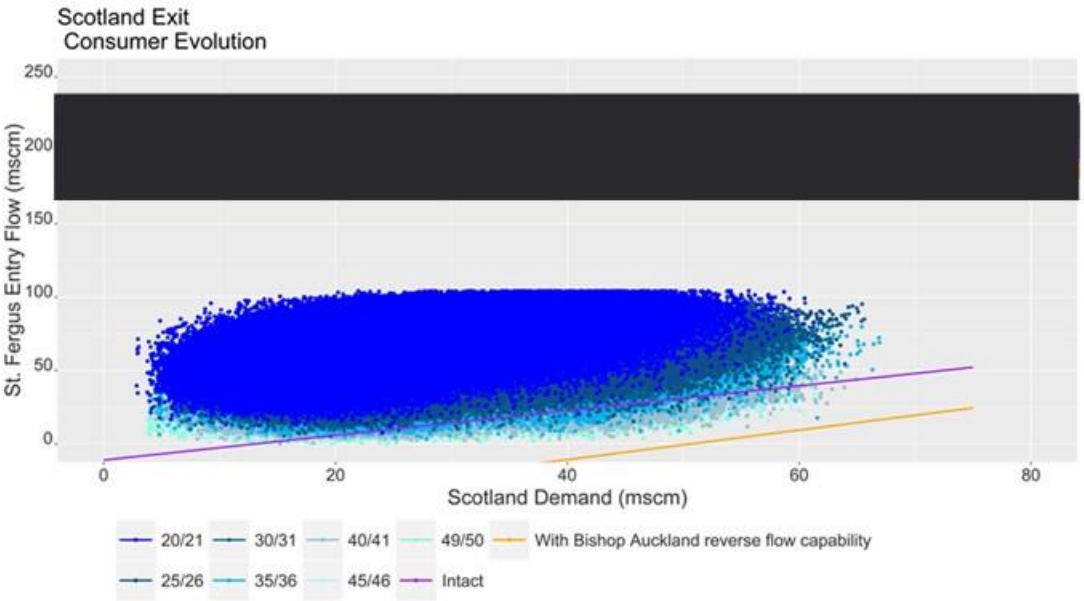
[6] Each dot on the chart is associated with one day in that year and for every day there are 1000 alternative supply and demand patterns. The different coloured dots are for different years showing how we expect supply and demand patterns to change over time.

Figure B9: Scottish Exit Capability (Two Degrees scenario)



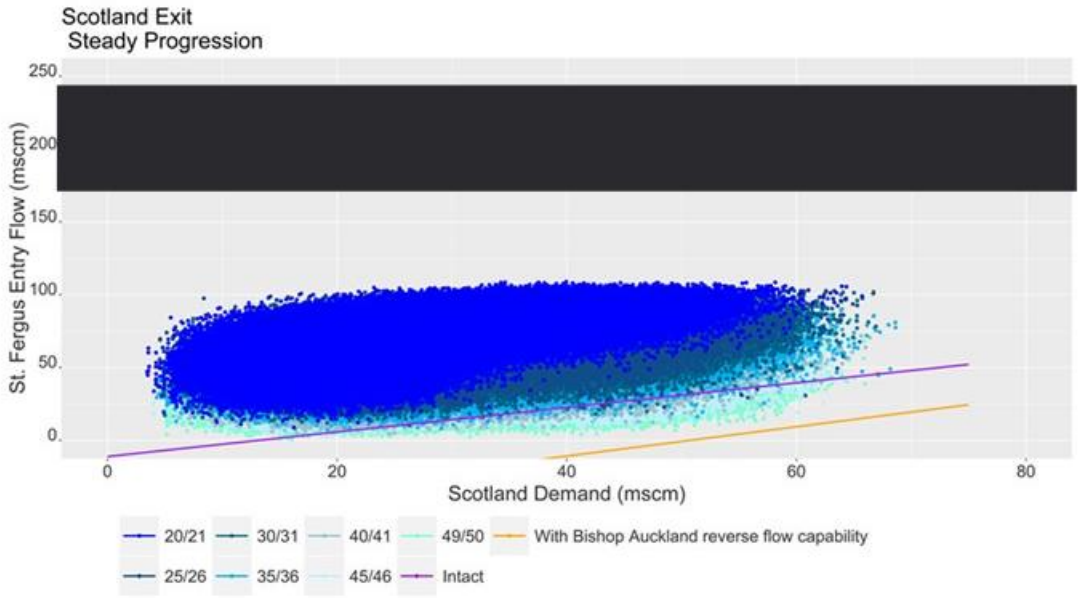
This scenario shows we would need reverse capability from 2030.

Figure B10: Scottish Exit Capability (Consumer Evolution scenario)



This scenario shows we would need reverse capability from 2035.

Figure B11: Scottish Exit Capability (Steady progression scenario)



In this scenario we have sufficient capability with the current network until 2040. This is the latest date that we would need the sites to be reversed but does confirm that all four scenarios will require the South to North capability in the future. This scenario shows a much slower decline in St Fergus supplies meaning Carnforth/Nether Kellet and Bishop Auckland are still required to support bulk transmission to the South.

Conclusions

Bishop Auckland and Carnforth/Nether Kellet currently play a critical role to support bulk transmission of gas from Scotland and the North of England to the South, supporting delivery of our entry capacity obligations at St Fergus, Teesside and Easington.

With planned closures of other compressors on the network, these sites will continue to play a key role whilst entry flows in the North remain high and to meet the requirements of customers in the North West and North East.

In the longer term, under all the FES scenarios we will require new capabilities to move gas South to North to meet the needs of Scottish gas consumers and to meet our 1 in 20 licence obligation in Scotland. The earliest requirement for reverse capability is in 2025 in the community renewables scenario. The latest requirement is in 2040 in the steady progression scenario. We have identified that Bishop Auckland and Carnforth/Nether Kellet compressors reconfigured to compress North, represent the best option to achieve the required capability and to provide resilience of this capability.

Section C – Churchover, Felindre and Alrewas

Executive Summary

Compression at Felindre, Wormington, Churchover and Alrewas are all primarily required to deliver the higher levels of entry capability required by customers at the Milford Haven LNG terminal. These entry flows are the single biggest constraint risk on the system currently, during RIIO-2 and beyond.

Other compressor sites can't provide back up for these sites, making it critical that these sites are retained and have the right level of back up (resilience). Even with our RIIO-2 plan, which retains compression at all these sites there is a risk of South Wales entry constraints, within the central forecast, to be in the range of [redacted][7]. Any reduction in compression at these sites, or reduction in availability of these compressors would lead to a significant increase in the level of risk and consequentially constraint costs.

In addition to meeting Milford Haven entry flows, the compressors at Alrewas, Churchover and Felindre provide the ability to meet other customer and consumer needs, including:

- Meeting consumer demand in South Wales - Churchover and Alrewas can be used to support the exit pressures in South Wales when entry levels at the Milford Haven terminal are low and demand in South Wales is high.

- Bulk transmission to meet customers entry and exit requirements – Alrewas is required to achieve the maximum required levels of North to South transmission at peak demand when supplies in Scotland and the North are high. Alrewas, along with Carnforth/Nether Kellet, provide resilience to Hatton if the station is on outage[8].

- Meeting customer requirements at North West storage sites – Alrewas is the only compressor station that can operate fully in any direction (i.e. it has the ability to compress gas towards or away from the North West). It can therefore support the exit and entry pressures required at the North West storage sites and help manage pressures for other customers in this region.

[7] Further detail on the risk analysis underpinning this cost range, can be found in the constraint management section of the Incentives annex A3.03
[8] Further detail on Carnforth/Nether Kellet and bulk transmission via the East and West Coast transmission routes can be found in Section B of this annex.

Background

Figure C1: The location of the key compressor sites on the NTS to support supply and demand in the South Wales.

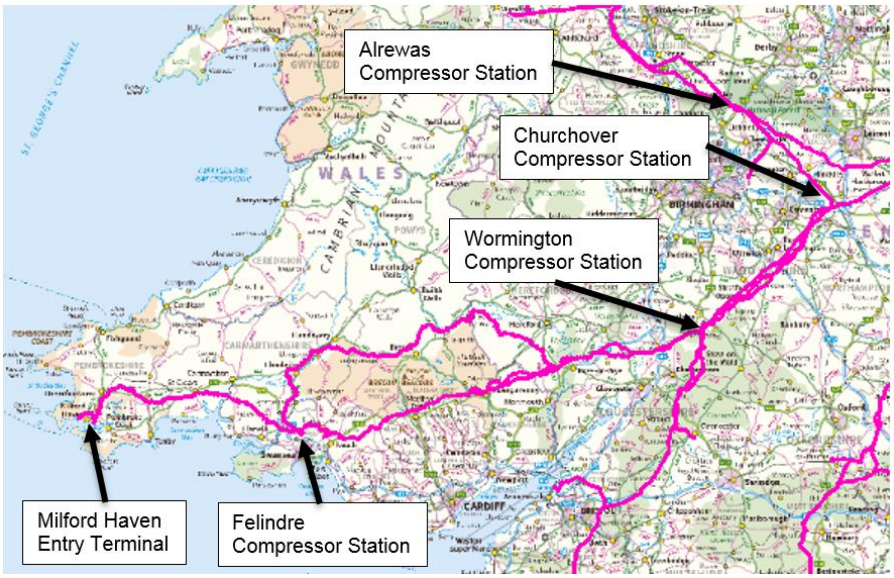


Table C2, shows the run hours for the three sites over the last five years. Felindre has seen the lowest levels due to the site only being operationally accepted since the end of 2017 and is only used when supplies are very high through the Milford Haven terminal.

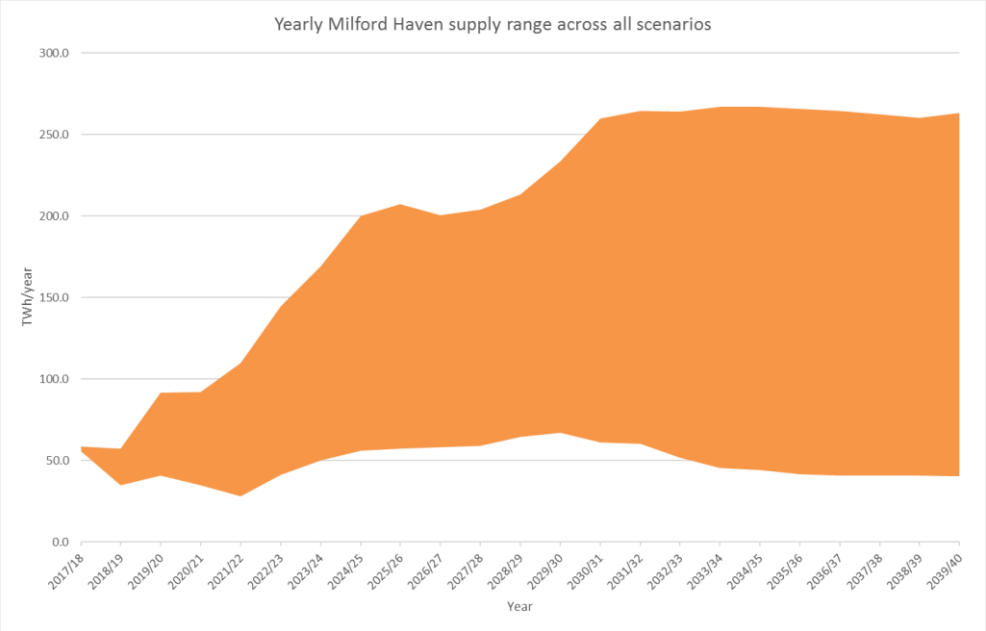
Table C2: Compressor running hours

	14/15	15/16	16/17	17/18	18/19
Alrewas	106	129	55	1734	638
Churchover	224	727	2447	249	160
Felindre	0	7	23	7	38
Total	**330**	**863**	**2525**	**1990**	**837**

Changes in supply and demand

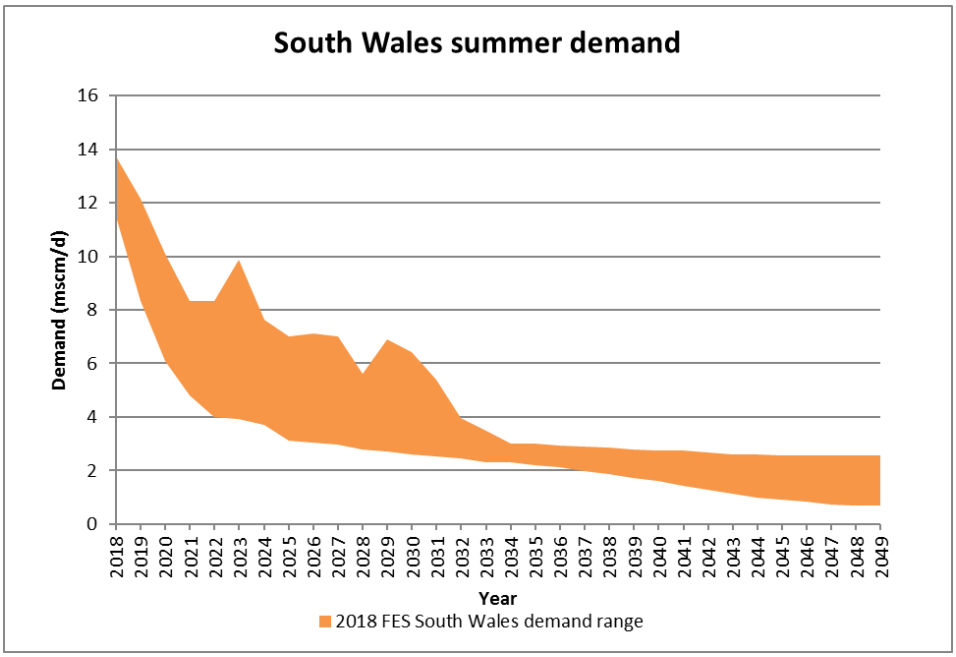
Over the next 20 years, supplies from the UKCS will continue to decline. The FES 2018 scenarios consider a range of possible sources that could replace these, including development of other indigenous sources, higher imports (pipeline or LNG), shale gas, biomethane and bio-substitute natural gas (bioSNG). Three of the four FES scenarios show an increase in imported gas either from Continental Europe or LNG. The highest scenario for LNG flows is the Two-Degree FES scenario where we would see LNG supplies double by the end of RIIO-2 and could be five times the level seen today by 2030. The FES range of potential Milford Haven flows is shown in Figure C3.

Figure C3: FES 2018 Range of Milford Haven entry flows



Summer demand in South Wales is expected to reduce under all of the FES 2018 scenarios, this reduction is due to mainly to assumptions on power station demand and to a lesser extent, a reduction in Gas Distribution Network demand (Figure C4).

Figure C4: FES 2018 Range of summer demand between Milford Haven and Churchover (South Wales demand)



Meeting customer's Milford Haven entry requirements

The combination of potentially higher entry flows into South Wales combined with a reducing demand in South Wales, means that higher volumes of gas will need to be transported out of South Wales and to customers elsewhere in the network. This leads to an increased requirement to operate the compressors at Wormington[9], Churchover, Felindre and Alrewas.

Network analysis has been undertaken to show the requirement for compression at Alrewas, Felindre and Churchover to support Milford Haven entry flows. This analysis has been undertaken against the four FES 2018 scenarios, each with imports under a High Continent and High LNG basis (i.e. 8 scenarios in total). Figure C5 shows the different combinations of compressors analysed for each of the 8 scenarios. These combinations allowing the impact of removing certain compressors from the network on the number of days of constraints on the network to be determined.

Figure C5: Asset assumptions for the Network Analysis

Name	Colour[10]	Wormington	Churchover	Felindre	Alrewas
Intact	Purple	On (2 units)	On	On	On
Intact (No Alrewas)	Orange	On (2units)	On	On	Off
Intact (Wormington C only)	Green	On (1 unit)	Off	Off	Off
No Compression	Yellow	Off	Off	Off	Off

The result of the capability analysis using the different asset assumptions against the 8 scenarios is shown in Figures C6 to C13. The dots on the chart show customer requirements, from the FES 2018 scenarios[11]. The table at the top of the chart shows the number of dots above the capability line(s) translated into the forecast number of constraint days.

The charts show that the different FES 2018 scenarios result in a wide range of potential constraint days at the Milford Haven terminal. In the worst-case scenario for constraint risk, Two Degrees (Figure C6), with the planned compressors 100% available, by the 2040s we forecast a risk of terminal constraints on [redacted] days per year. This level of constraint risk increasing further by the 2050s.

In all the scenarios showing constraint risk, if any of the compressors are not available at any one of the three sites (Churchover, Alrewas and Felindre), the number of days of constraint risk increases.

[9] Justification for our RIIO-2 investment at Wormington is contained in Annex A16.10 and A16.11
[10] Colour refers to the colour of the capability lines shown in the Figures C6 to C13
[11] Each dot on the chart is associated with one day in that year and for every day there are 1000 alternative supply and demand patterns. The different coloured dots are for different years showing how we expect supply and demand patterns to change over time.

Figures C6 to C9 show the network capability plots for the High LNG scenarios where imports are prioritised through the LNG terminals.

Figure C6: Network entry capability at Milford Haven (Two Degrees 2018 – High LNG)

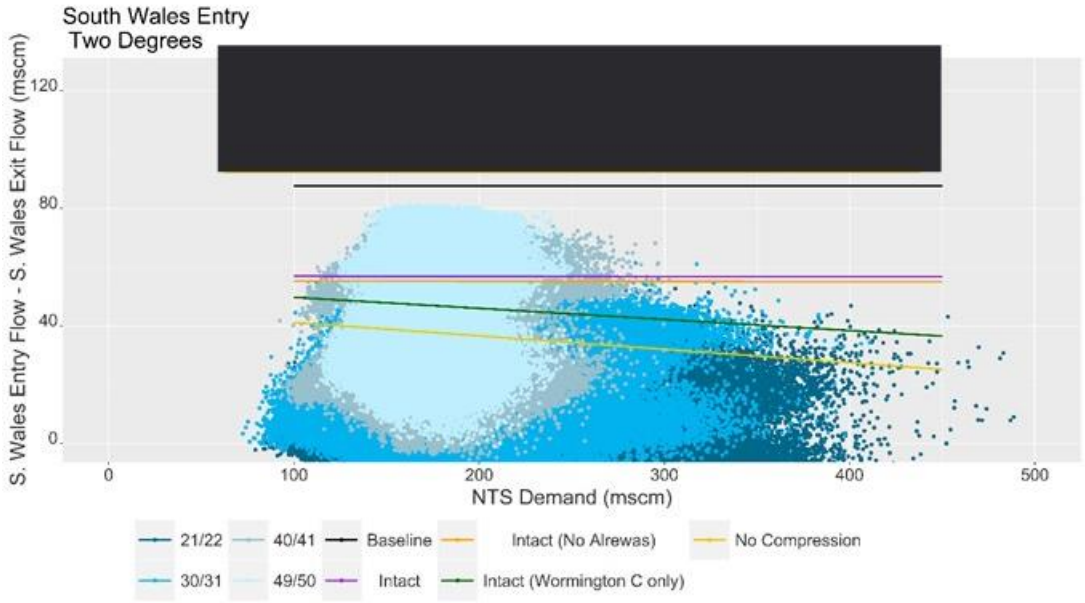


Figure C7: Network entry capability at Milford Haven (Steady Progression 2018 – High LNG)

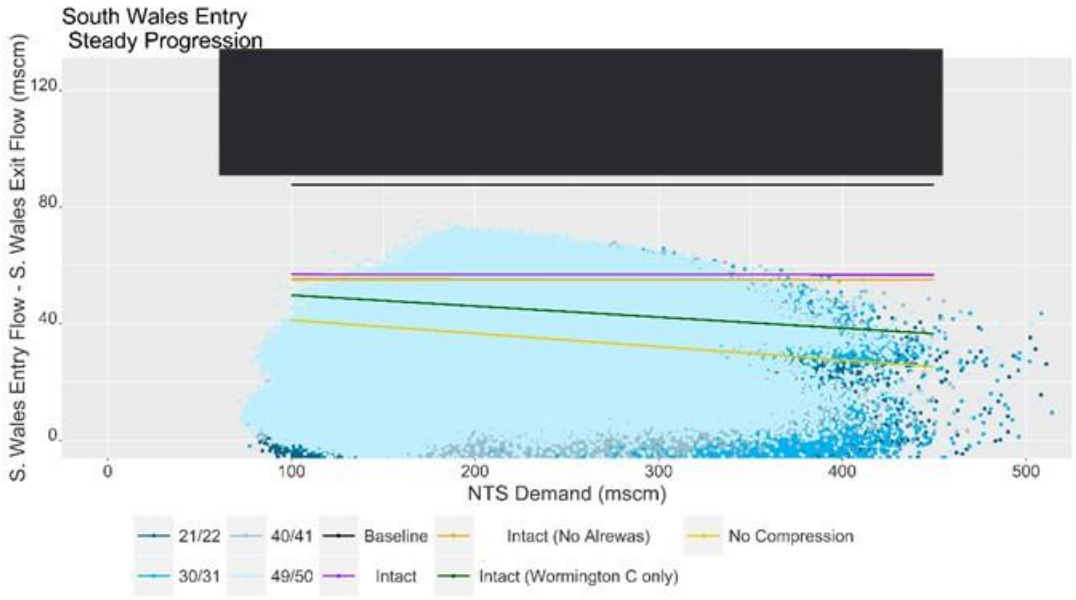


Figure C8: Network entry capability at Milford Haven (Community Renewables 2018 – High LNG)

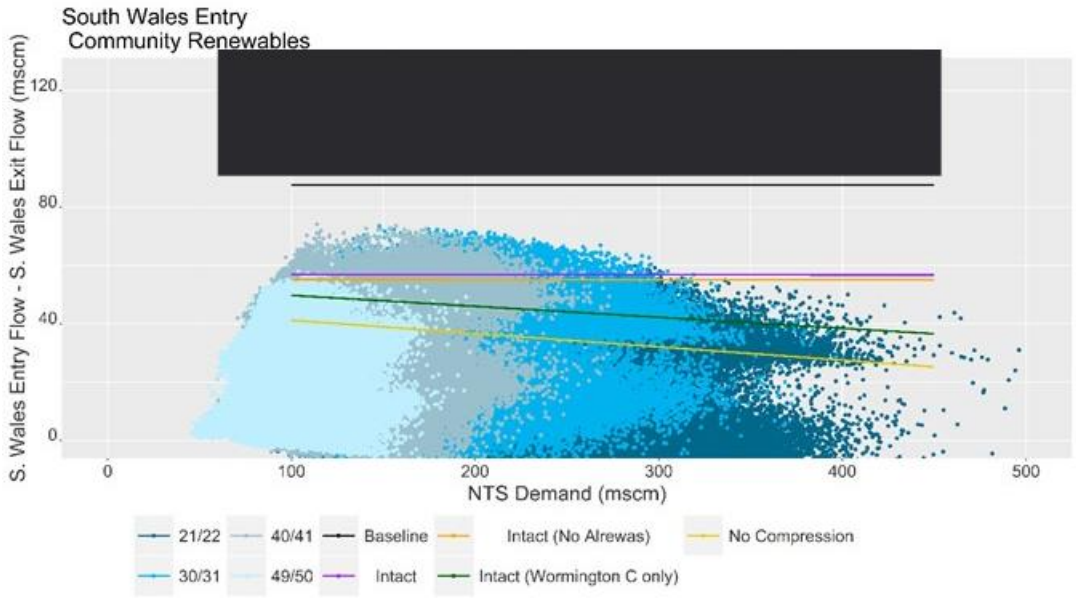


Figure C9: Network entry capability at Milford Haven (Consumer Evolution 2018 – High LNG)

Figures C10 to C13 show the High Continental network capabilities. In these scenarios' imports are prioritised from Europe through the interconnectors. These show a similar trend to the high LNG plots but with reduced constraint risk levels.

Figure C10: Network entry capability at Milford Haven (Two Degrees 2018 – High Continental)

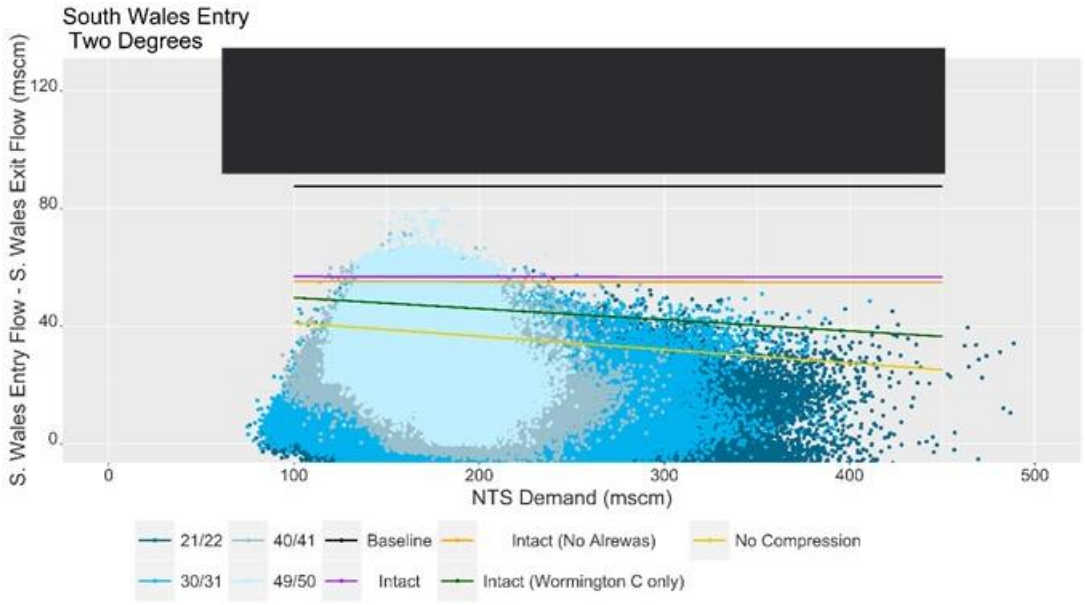


Figure C11: Network entry capability at Milford Haven (Steady Progression 2018 – High Continental)

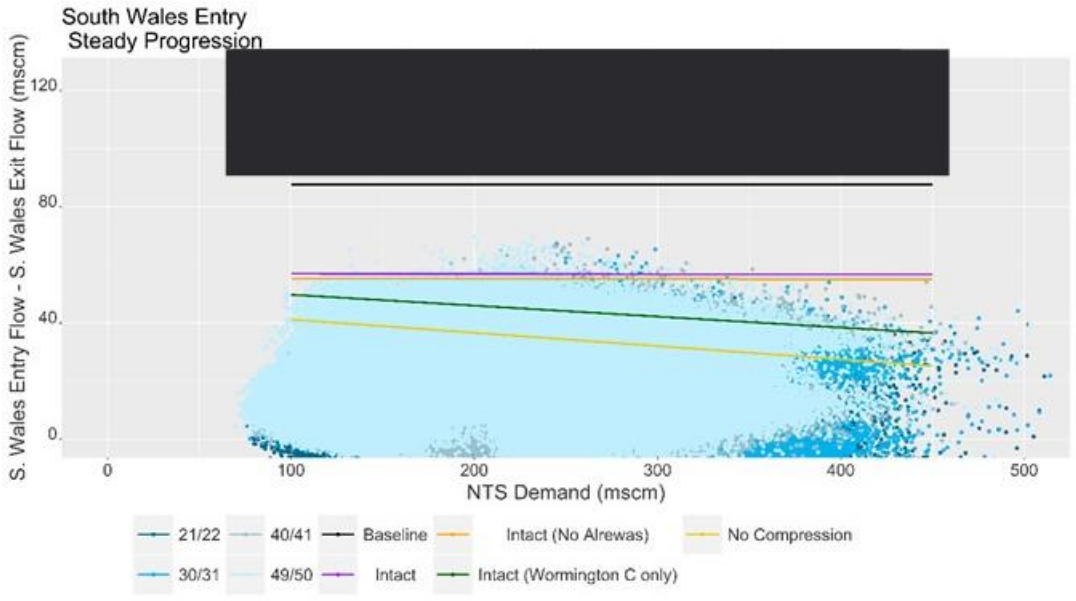


Figure C12: Network entry capability at Milford Haven (Community Renewables 2018 – High Continental)

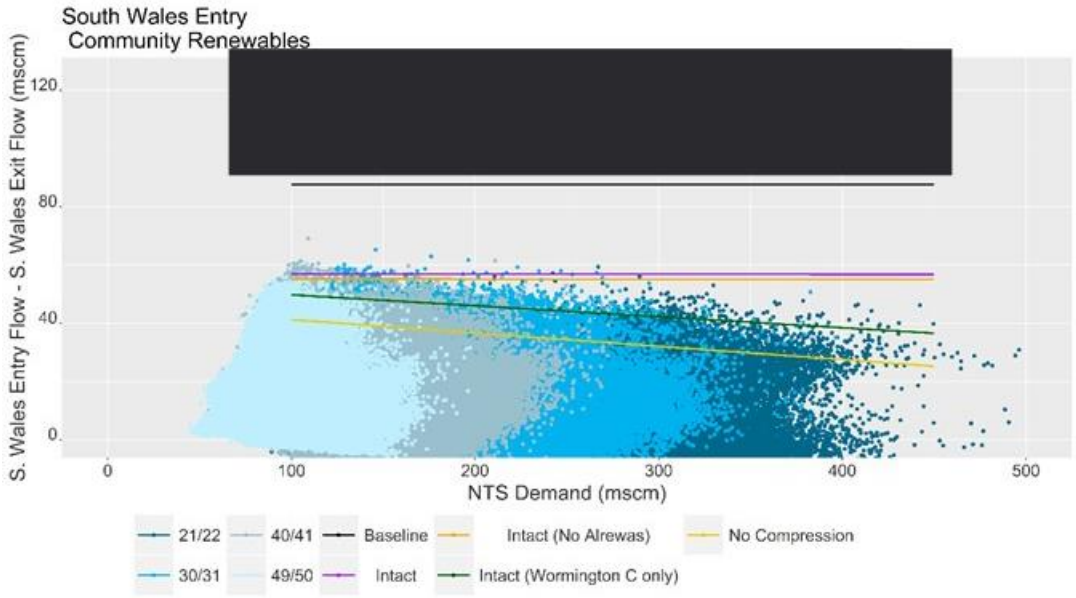


Figure C13: Network entry capability at Milford Haven (Consumer Evolution 2018 – High Continental)

The network capability plots show how, in the Two Degrees and Steady Progression scenarios, the risk of constraints increases over time. This is similar in the Community Renewables scenario but after 2040 the risk of constraints starts to decline by 2050. Consumer Evolution is the low case, this is because it is the high case for UK shale gas production. This reduces the UK import dependency resulting in less of a requirement for imports.

These network capability charts show how the risk of constraints increases due to the declining UKCS supplies and increased import dependency based on FES 2018. This gives a good indication of the future entry risk for the Milford Haven terminal. What they do not accurately reflect are the historic flows seen through the Milford Haven terminal during the boundary months (September/November

and March/May) or information provided by the customer on future flows. For this reason, two additional sensitivities have been completed:

Uniform – This replaces the FES 2018 supply forecast for Milford Haven with a uniform distribution. This means that Milford Haven supply can be anything from zero to around 86 mcm/d as a proxy for non-seasonal behaviour.

Historic – This replaces the FES 2018 supply scenarios for South Wales with historic supplies as a proxy for RIIO-2 supply behaviour.

To determine the current level of risk a combination of the three approaches has been used. It is weighted towards FES by proportioning the constraints found in each of the approaches by the number of scenarios. (8 FES scenarios vs 1 uniform and 1 historic). Table C14 shows the average number of events under the three approaches before and after they are weighted.

Table C14: Average number of events before and after weighting

Average Events	21/22	22/23	23/24	24/25	25/26
FES	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Uniform	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Historic	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Weighted Events					
FES	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Uniform	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Historic	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Total	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Figure C15 shows the level of constraint cost risk currently being managed during RIIO-2. This assumes that all compression at Wormington, Felindre, Churchover and Alrewas is maintained to the current levels of availability. These have been calculated using the same constraint methodology as used for the Constraint Cost Management incentive[12].

Figure C15: Average South Wales constraint cost risk with the intact network

This shows the level of risk forecast for the RIIO-2 period. Failure to maintain the current compression would result in reduced availability of these key sites resulting in an increase in the constraint risk.

[12] See Annex A3.03

Milford Haven ASEP Planning and Advanced Reservation of Capacity Agreement (PARCA)

An application is progressing through the PARCA process[13] to increase the entry baseline at the Milford Haven terminal. Increased flows from Milford Haven would increase the level of constraint risk and options to mitigate these are being evaluated. The Strategic Options Report (SOR) for the customer is currently being finalised. All the options considered will further increase the requirement for compression to meet customer's requirements.

Additional benefits of compression at Churchover, Felindre and Alrewas

In addition to meeting the entry requirements at Milford Haven, compressors at Churchover, Felindre and Alrewas provide additional customer and consumer benefits. These are summarised below:

Meeting Customer Demand in South Wales

When flows entering the network at Milford Haven terminal are low and demand is high in South Wales, Wormington or Churchover can be used to support the required exit pressures and ensure supply and demand remains balanced in the area. The preferred site to support the demands would be Churchover due to need to support Assured Operating Pressures (AOPs) in the West Midlands.

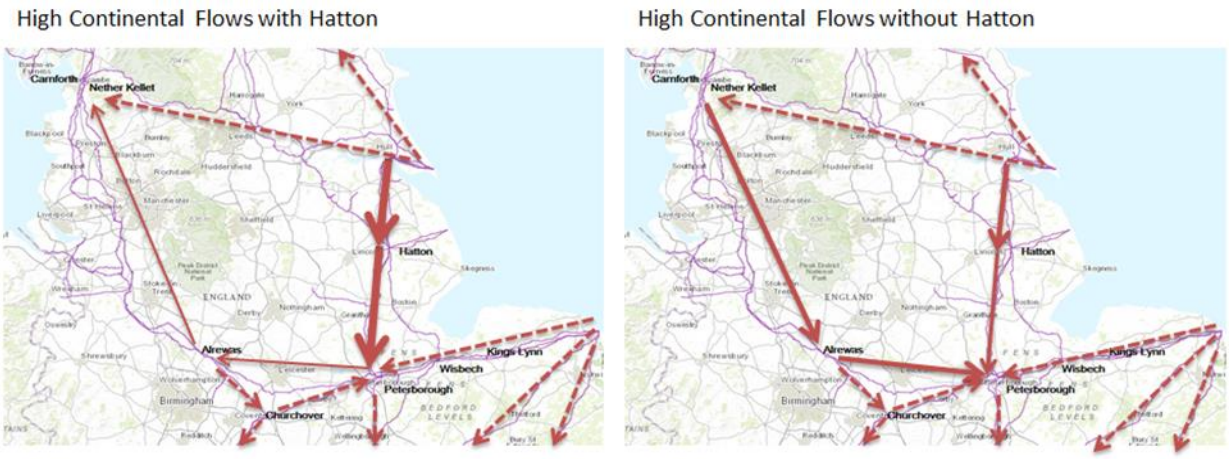
North West storage

Alrewas is the only compressor station that can operate fully in any direction on network. This flexibility allows it to support exit pressure at the storage sites when they are filling and can support entry pressures when the sites are emptying. With UKCS supply levels declining there will be an increasing requirement to transport gas from the South to the North which only Alrewas can do currently.

Bulk transmission

With high gas flows from St Fergus and Easington, the preferred route to transport gas South is down the East Coast transmission route. This is shown with the dark red arrows on the diagram on the left-hand side of Figure C16, with gas flowing through Hatton onwards to Peterborough. If Hatton is not operating, compression on the West coast can offer resilience as can be seen diagram on the right-hand side of Figure C16. Under peak conditions with very high entry levels in the North both the East and West Coast compression will be used to support the demands in the South.

Figure C16: East and West Coast bulk transmission routes



[13] https://www.nationalgridgas.com/connections/reserving-capacity-parca-and-cam

Conclusions

The primary requirement for compression at these three sites is supporting high levels of gas entering the Milford Haven terminal. Any reduction in compression at Felindre, Churchover or Alrewas would have a direct impact on the expected number of constraint days and associated costs. Even with the proposed compression at these sites, the constraint risk is forecast to be in the range of [redacted] per annum during RIIO-2 and this level is expected to increase in scenarios with increased LNG flows. It is therefore important to continue to invest in the assets at Alrewas, Churchover and Felindre to retain high levels of availability now and into the future.

In addition, these compressor sites also support meeting consumer demand in South Wales (when Milford Entry flows are low), bulk transmission of gas from North to South to meet customer entry and exit requirements and managing pressures in the North West.

Section D - Diss, Chelmsford and Cambridge

Executive Summary

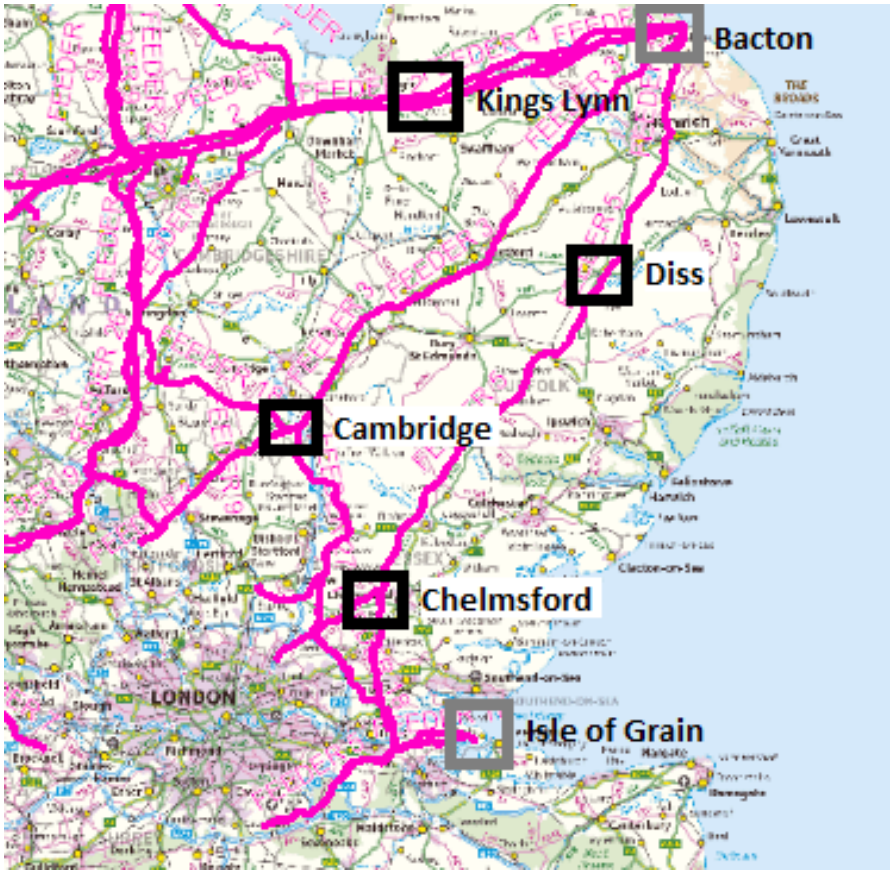
Compressors at Cambridge, Chelmsford and Diss are used to ensure supplies to consumers in the South East, meet our 1 in 20 licence obligation and to provide entry capability at the Bacton and Isle of Grain terminals.

Under the range of FES 2018 scenarios, this level of compression is required to at least 2038, and potentially beyond 2050 to maintain compliance with our 1 in 20 licence obligation in the South East. The alternative to using compression to meet our 1 in 20 licence obligation, would be to enter into turn-down contracts with large consumers in South East (e.g. power stations) or turn-up contracts for additional supplies at the Isle of Grain LNG terminal. For the RIIO-2 period our median cost estimation of these costs is between [redacted]. We believe this median cost estimation to understate the actual costs as it uses actual OM contract prices for procurement of a smaller volume and hence procurement of a larger volume could be expected to require acceptance of higher tender prices.

Background

The South East of the network is a complex area with many variables that impact on how we utilise assets to support the supplies and demands in the area and to meet our obligations. The key sites in the area can be seen in Figure D1.

Figure D1: Key compressor and terminal sites in the South East



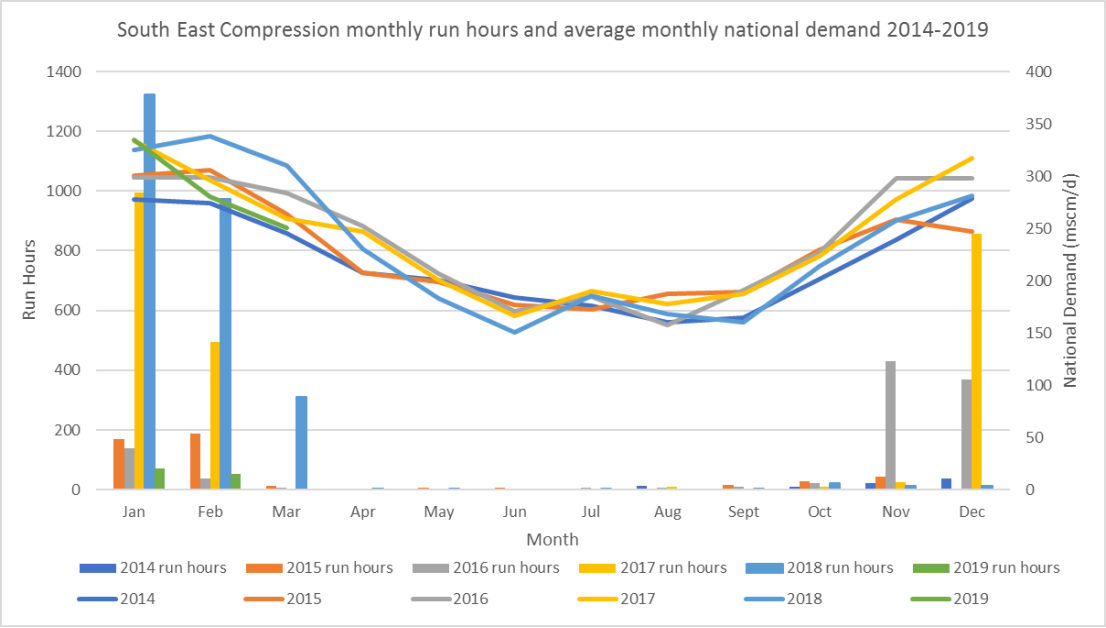
The compressors at Diss, Chelmsford and Cambridge are used to meet customer's entry capability requirements at Bacton and to meet consumer's demand needs in the South East. The compressor at Cambridge also supports meeting our customer's entry capability requirements at the Isle of Grain terminal. Table D2 shows the run hours from the three compressor sites for the last 5 years.

Table D2: Historic compressor run hours

	14/15	15/16	16/17	17/18	18/19
Diss	145	46	1120	2058	72
Chelmsford	111	34	880	1073	69
Cambridge	211	216	340	387	45
Total	**467**	**296**	**2340**	**3518**	**186**

The use of the compressors in the South East has historically occurred in Winter (November to March) at higher (above 300 mscm/d) National demand levels (Figure D3).

Figure D3: Monthly run hours vs National Demand

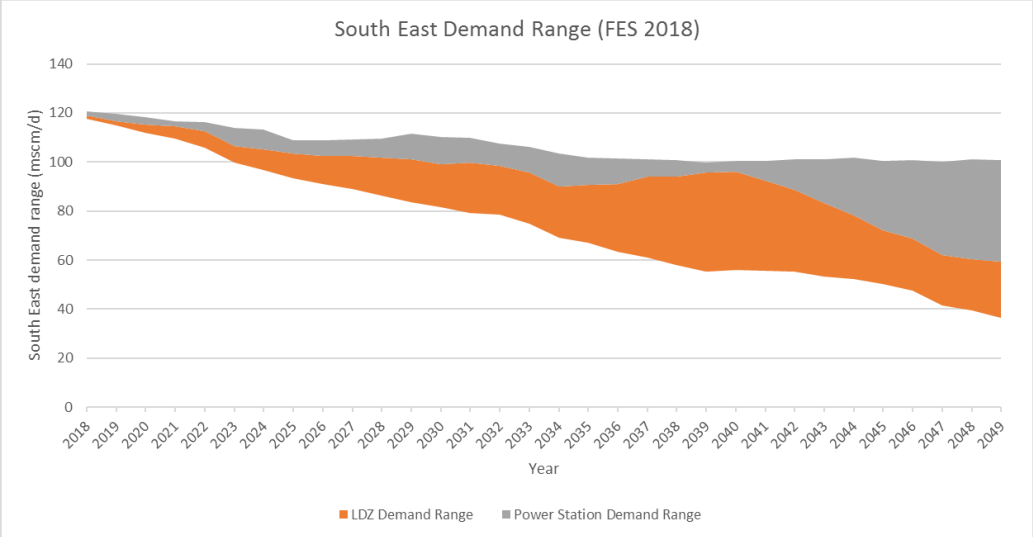


Changes in supply and demand

South East Demand

The South East is one of the largest demand areas on the network and includes key offtakes supplying London and several gas fired power stations. The FES 2018 shows a generally reducing trend in demand in the South East across all 4 scenarios but there is uncertainty on the timing and magnitude of this reduction (Figure D4). Reducing demand in the South East would subject to supply patterns, generally be expected to result in a reducing requirement for compression in the South East.

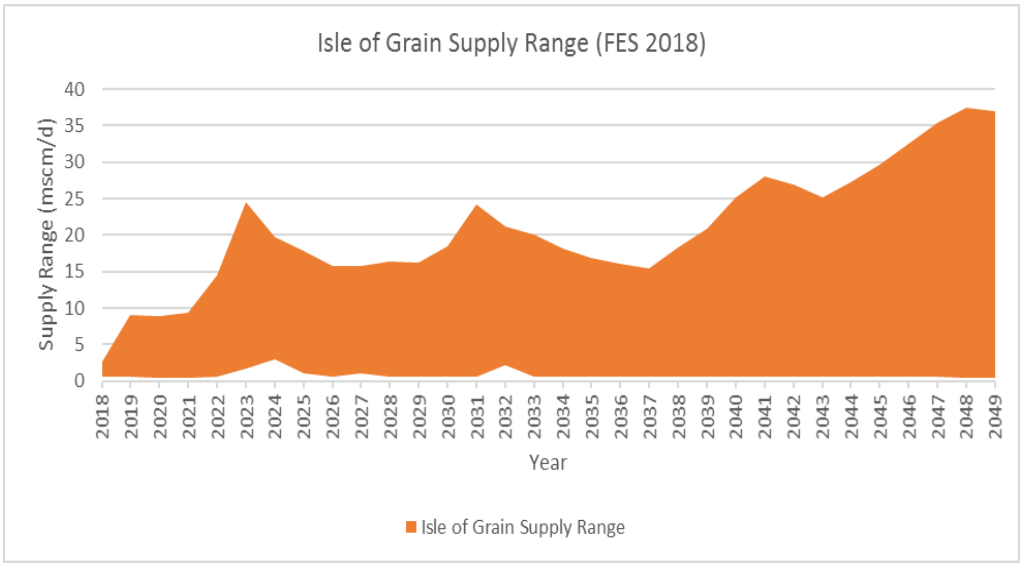
Figure D4: FES South East Demands



South East Supplies (Isle of Grain and Bacton)

FES 2018 scenarios show that we could see higher flows from the Isle of Grain terminal (Figure D5) which would reduce the need to operate compressors at Diss and Chelmsford to support South East demands but could potentially increase the need for Cambridge to support entry levels for the LNG terminal.

Figure D5: FES 2018 Isle of Grain supply range

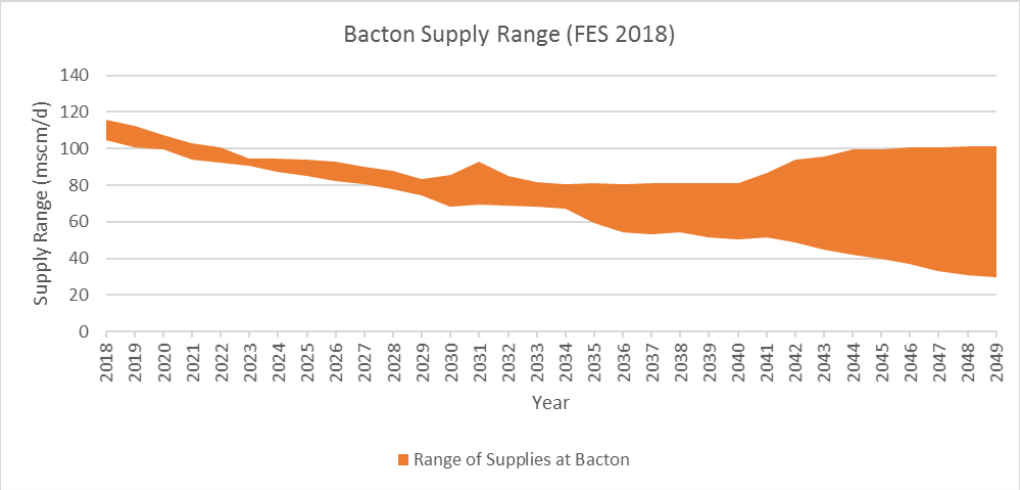


However, there is a great deal of uncertainty around the flows from the Isle of Grain and they cannot be relied upon to meet our 1 in 20 licence obligation in the South East (e.g. the LNG storage tanks could be empty following a spell of high demand). If Isle of Grain flows are assumed to be zero then compression at Diss and Chelmsford would need to be retained or commercial contracts would be required, until South East demand reduced to a level where they are no longer required.

Predicting gas flows and the need for compression in the South East is also complicated by the uncertainty over future flows at Bacton (Figure D6). The level of entry flows from Bacton has a large

impact on the compressors in the South East. Historically supplies from Isle of Grain have been low and gas entering Bacton is directed towards the South East with only the excess volumes flowing East towards Kings Lynn.

Figure D6: 2018 FES Bacton supply range



Future compression requirements

We have undertaken analysis to show the requirement for retaining compression at Cambridge, Chelmsford and Diss to meet our 1 in 20 licence obligation, and to determine the impacts should levels of compression be reduced.

The results of this analysis are shown in Figures D8 to D11. The charts show the capability under different compression assumptions (Figure D7) compared to the 1 in 20 licence obligation (black line on the charts).

Figure D7: Combinations of compressors assumed in the analysis

Line Colour	Name	Peterborough and Huntington	Cambridge, Chelmsford and Diss
Orange	Intact	On	On
Yellow	No Cambridge, Chelmsford and Diss	On	Off

Figure D8: Ability to meet our 1 in 20 Licence Obligation, with and without compression at Cambridge, Chelmsford and Diss (Steady Progression Scenario)

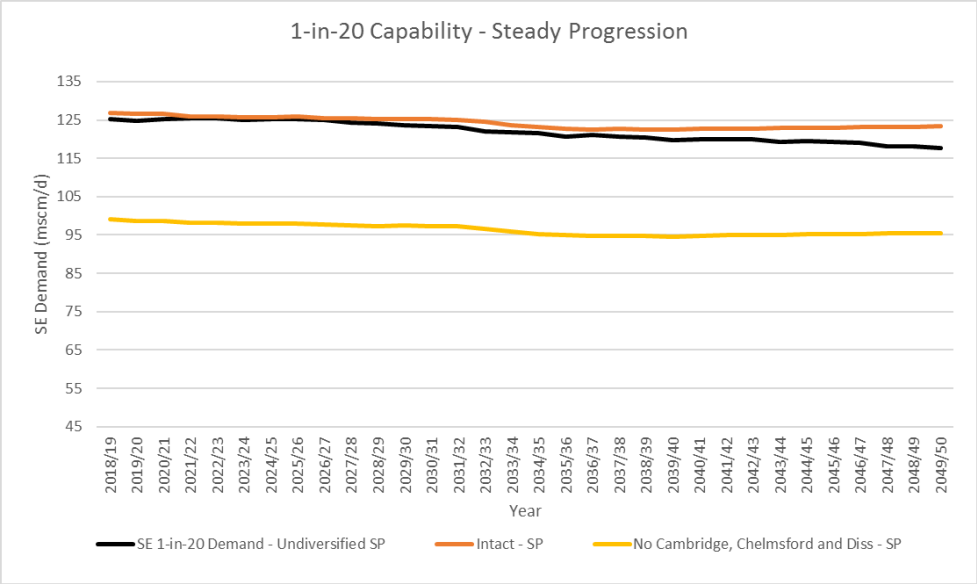
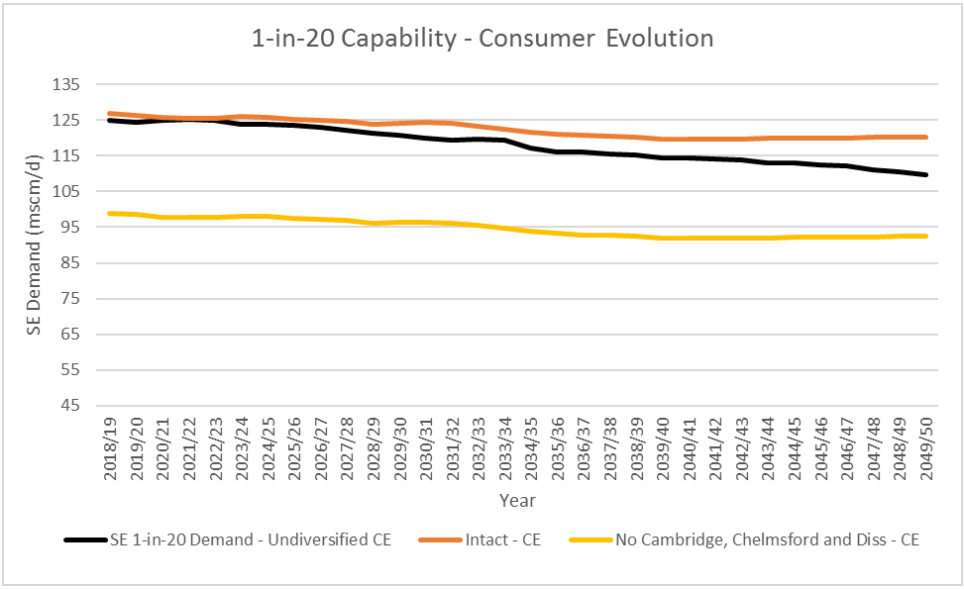


Figure D9: Ability to meet our 1 in 20 Licence Obligation, with and without compression at Cambridge, Chelmsford and Diss (Consumer Evolution Scenario)



Figures D8 and D9 show that under 2 of the FES scenarios, compression is required at Cambridge, Chelmsford and Diss beyond 2050 to meet our 1 in 20 licence obligation.

Figure D10: Ability to meet our 1 in 20 Licence Obligation, with and without compression at Cambridge, Chelmsford and Diss (Community Renewables Scenario)

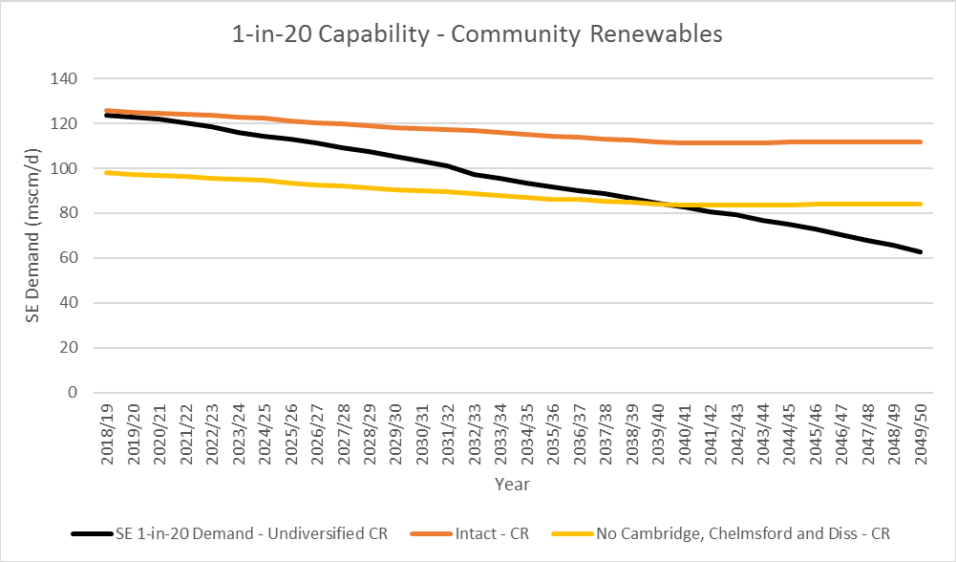
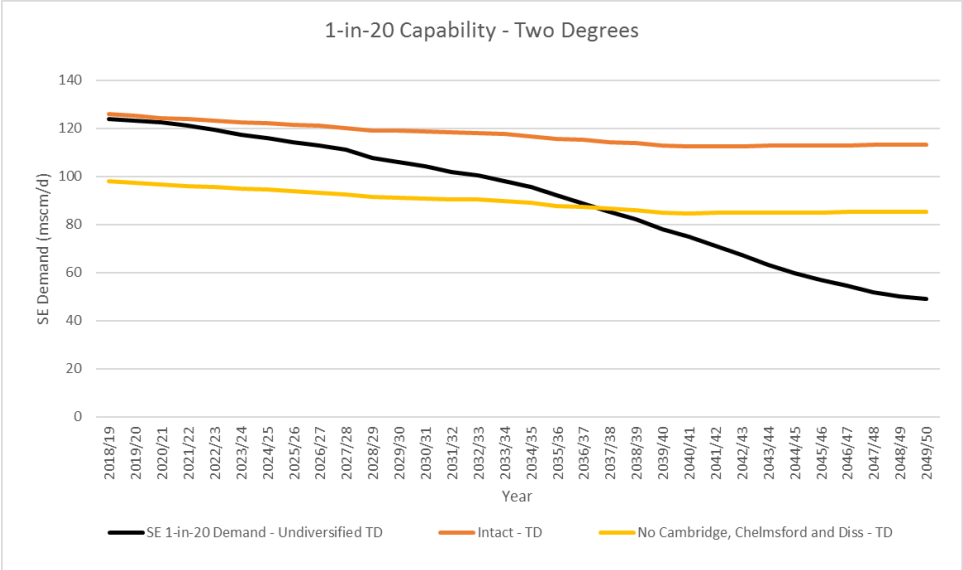


Figure D11: Ability to meet our 1 in 20 Licence Obligation, with and without compression at Cambridge, Chelmsford and Diss (Two Degrees Scenario)



Figures D10 and D11 shows 2 of the FES 2018 scenarios have a reducing requirement for compression to meet our 1 in 20 licence obligation. The earliest date for no compression requirement being 2038 in the two degrees scenarios. Under both of these scenarios' compression at Cambridge, Diss and Chelmsford is required to meet our 1 in 20 licence obligation until at least 2032.

Contract options to meet 1 in 20 licence obligation

The alternative to compression at the three sites, in order to maintain compliance with our 1 in 20 licence obligation, would be either turn-down contracts with large demand in the [redacted] or a turn-up contract [redacted]. Figure D12 shows the contract volumes required without compression at Cambridge, Chelmsford and Diss. It shows that to be compliant with the 1 in 20 licence obligation we would need to contract for 27.8 mscm/d in the early years of RIIO-2 under all FES scenarios and that in two of the four scenarios there is no reduction in the volume until after 2040.

Figure D12: Required contract volumes to meet 1 in 20 licence obligation without Cambridge, Diss and Chelmsford compressors

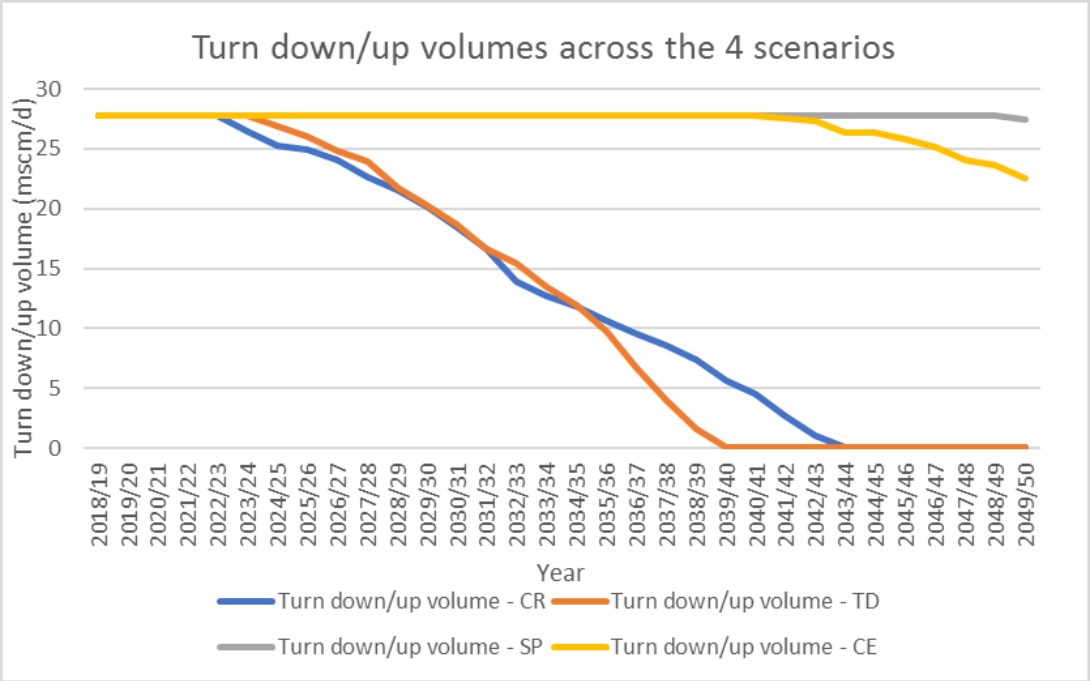


Figure D13 gives an estimate of the potential contract cost range under the four scenarios. These figures are based on bids received for the 2019 OM contracts in the South East area, assuming the contracts are with large power generators or the Isle of Grain entry terminal. The low case is based on the weighted average of all bids accepted in this tender and the median cost is based on the highest bid accepted. For the high case the increased volume we would need to procure, would result in a need to accept tender prices well beyond those accepted in the recent tender. For the purposes of this high scenario, we have assumed prices could be up to three times greater than the median as we would need to book eight times the volume contracted in the South East under the 2019 OM tender[14].

In our median case, the range of costs is [redacted] during RIIO-2. Given the increased volume that would need to be contracted for compared to the OM tender, we expect that this will be an underestimation of the contract costs to remain compliant with our 1 in 20 licence obligation.

[14] Our 1 in 20 licence obligation requirements is up to 27.8 mscm/d. In our 2019 OM tender we contracted for 3.2 mscm/d in the South East. www.nationalgridgas.com/document/128216/download

Figure D13: Estimated contracting cost during RIIO-2 to deliver compliance with our 1 in 20 Licence Obligation

Conclusions

Compressors at Cambridge, Chelmsford and Diss are used to ensure supplies to consumers in the South East, meet our 1 in 20 licence obligation and to provide entry capability at the Bacton and Isle of Grain terminals.

Under the range of FES scenarios, this level of compression is required to at least 2038 and potentially beyond 2050, to maintain compliance with our 1 in 20 licence obligation in the South East. The alternative to using compression to meet our 1 in 20 licence obligation, would be to enter into turn-down contracts with large consumers in South East (e.g. power stations) or turn-up contracts for additional supplies at the Isle of Grain LNG terminal. For the RIIO-2 period our median cost estimation of these costs is between [redacted]. We believe this median cost estimation to understate the actual costs as it uses actual OM contract prices for procurement of a smaller volume and hence procurement of a larger volume could be expected to require acceptance of higher tender prices.

Section E - Lockerley

Executive Summary

Lockerley compressor station is located near to the Hampshire village of Lockerley on the Southern feeder (no. 7). The site contains two Variable Speed Drives (VSD) electric compressors detailed in Table E1. The units can operate in parallel if required but current demand levels only require single unit operation with the second unit providing back up for planned or unplanned outages.

Table E1: Existing Assets at Lockerley

Unit	Engine	Power Base (MW)	Installation Date	Nominal Capacity (mscm/d)	Maximum Discharge Pressure (barg)
A	Electric	8.0	2000	18	75
B	Electric	8.0	2000	18	75

Without this resilient compression at Lockerley, costs would be incurred as a result of network constraints and the need to enter into commercial turn-down contracts to meet our 1 in 20 licence obligation. For the RIIO-2 period our median cost estimation of these costs is between [redacted]. We believe this median cost estimate understates the likely actual costs as it uses actual OM contract prices for procurement of a smaller volume and hence procurement of a larger volume could be expected to require acceptance of higher tender prices.

Our RIIO-2 plan includes asset health work and deployment of cyber protection at Lockerley, it delivers the following benefits:

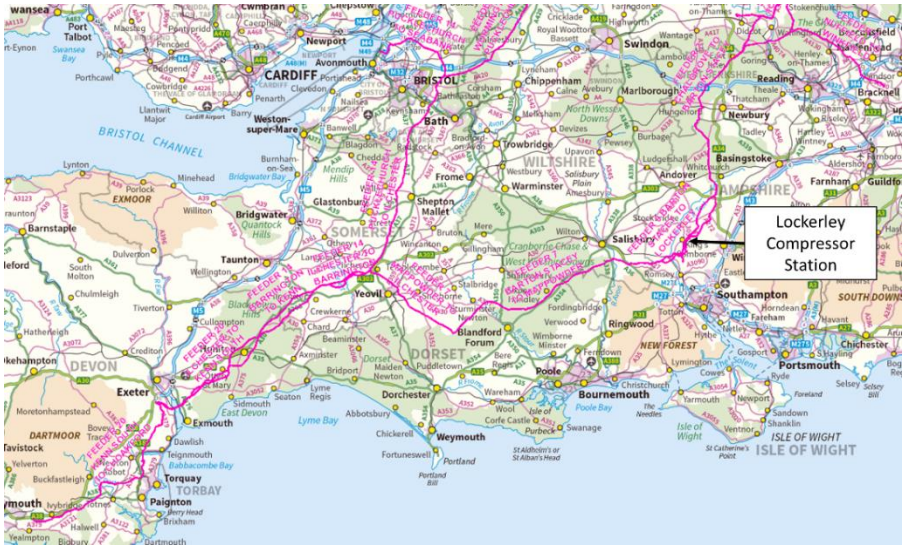
- compliance with the 1 in 20 licence obligation during RIIO-2. Under the different FES 2018 scenarios, the duration of the requirement for Lockerley to meet the 1 in 20 licence obligation ranges from until 2042 to beyond 2050

- delivery of our pressure obligations to the Distribution Networks, and therefore supplies to consumers in the South West.

Background

Lockerley compressor station is located on feeder 7 north of Southampton as shown in Figure E2.

Figure E2: Lockerley Compressor Station location

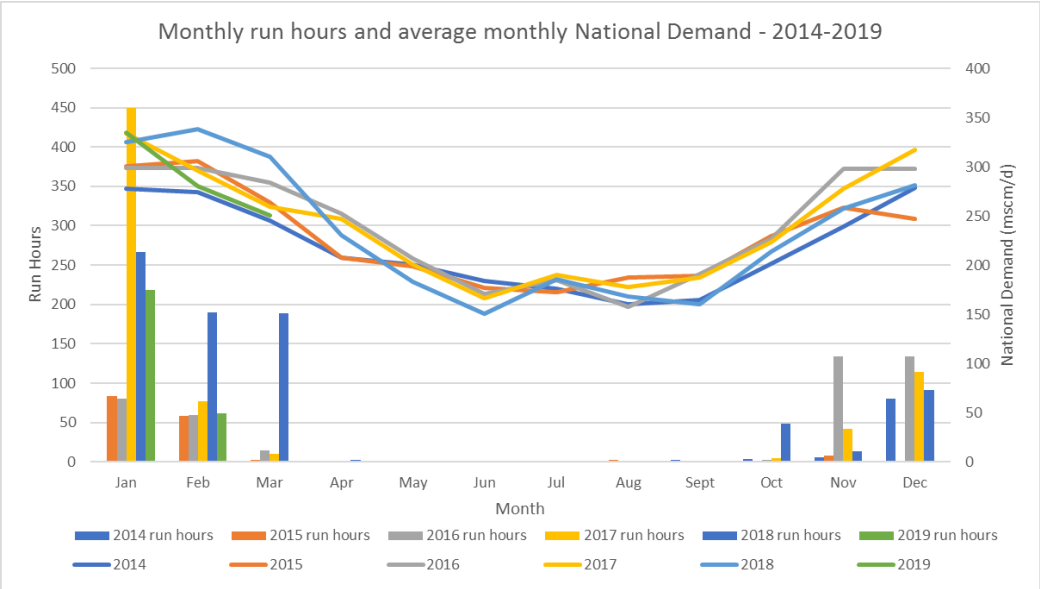


Whilst running hours are relatively low (Table E3), Lockerley is a critical compressor on the NTS. Without compression we would not comply with the 1 in 20 licence obligation and would need to enter into commercial turndown contracts or develop additional compression capability elsewhere on the network. Lockerley also delivers the necessary extremity pressures in the South West, particularly during winter demand (>280m mscm/d) and peak demand (480 mscm/d) conditions (see Figure E4), avoiding the need to undertake constraint actions.

Table E3: Running hours for Lockerley over the last 5 years.

	14/15	15/16	16/17	17/18	18/19
Lockerley	236	164	808	806	436

Figure E4: Running Hours at Lockerley, showing running hours occur during the winter months at times of higher national demand.



Note: The columns represent the monthly run hours (2014-2018) and the lines represent national demand (mscm/d).

Delivery of 1 in 20 Licence Obligation in the South West

We have undertaken analysis to asses our ability to meet the 1 in 20 licence obligation in the South West, with and without compression at Lockerley. Figures E4 to E7 show the outcomes under the four FES scenarios.

Figure E5: Ability to meet our 1 in 20 Licence Obligation, with and without Lockerley (Consumer Evolution Scenario)

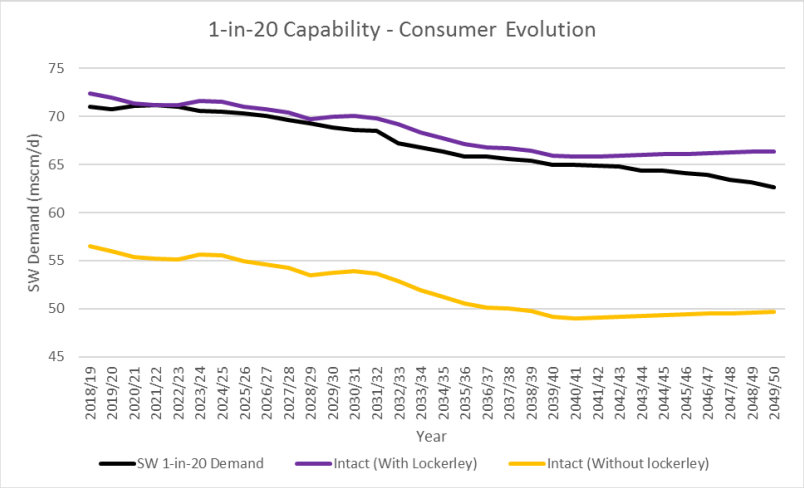


Figure E6: Ability to meet our 1 in 20 Licence Obligation, with and without Lockerley (Two Degrees Scenario)

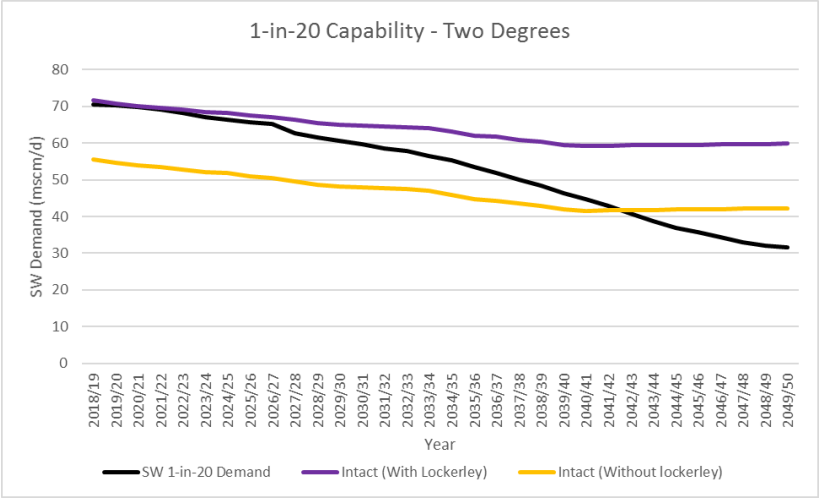


Figure E7: Ability to meet our 1 in 20 Licence Obligation, with and without Lockerley (Community Renewables)

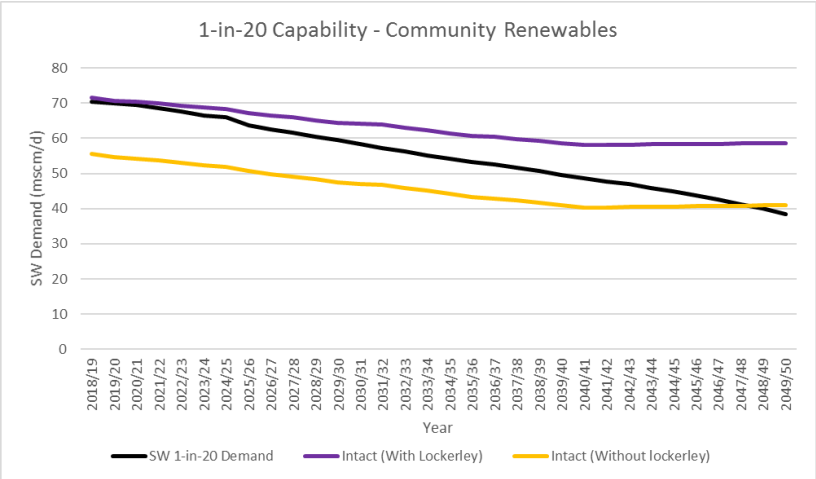
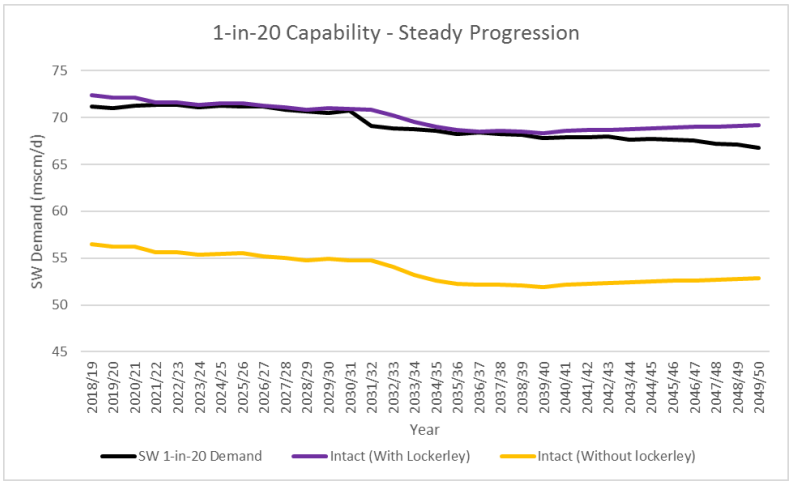


Figure E8: Ability to meet our 1 in 20 Licence Obligation, with and without Lockerley (Steady Progression)



Under all 4 FES scenarios Lockerley is required to meet our 1 in 20 licence obligation until at least 2042. Under 2 of the scenarios this requirement extends beyond 2050.

The alternative to compression at Lockerley in order to maintain compliance with our 1 in 20 licence obligation would be to enter into turn-down contracts with consumers in the South West.

Figure E9 gives an estimate of the potential contract cost range under the four scenarios. These Figures are based on bids received for the 2019 OM contracts in the South West area, assuming the contracts are with large power generators. The low case is based on the weighted average of all bids accepted in this tender and the median cost is based on the highest bid accepted. For the high case the increased volume we would need to procure, would result in a need to accept tender prices well beyond those accepted in the recent tender. For the purposes of this high scenario, we have assumed prices could up to three times greater than the median as we would need to book four times the volume contracted in the South West under the 2019 OM tender[15].

In our median case, the range of costs is [redacted] during RIIO-2. Given the increased volume that would need to be contracted for compared to the OM tender, we expect that this will be an underestimation of the contract costs to remain compliant 1 in 20 licence obligation.

[15] Our 1 in 20 licence obligation is up to 16.3 mscm/d. In our 2019 OM tender we contracted for 3.9 mscm/d in the South West. www.nationalgridgas.com/document/128216/download

Figure E9: Estimated costs of Turn Down contracts to meet 1 in 20 Licence Obligation (without Lockerley)

Delivery of gas to consumers in the South West

We have undertaken analysis that shows how Lockerley is critical to meeting consumer needs for gas in the South West during periods of high demands, avoiding the need to undertake disruptive and costly constraint actions.

Figures E10 and E13, show the capability available, with and without Lockerley (represented by the lines on the chart) and how this compares to customer needs under the four FES 2018 scenarios (represented by the dots on the chart[16]). The table at the top of the Figures show the resulting number of constraint days under the FES 2018 scenario in question. These tables show that there is a range of potential number days where we would need to undertake constraint actions in the South West during RIIO-2.

[16] The dots on the chart are taking from a tool created to predict how supply and demands on the network might change under the four future energy scenarios (FES). Each dot on the chart is associated with one day in that year and for every day there are 1000 alternative supply and demand patterns. The different coloured dots are for different years showing how we expect supply and demand patterns to change over time

Figure E10: Ability to meet consumer exit requirements in the South West, with and without Lockerley (Consumer Evolution Scenario)

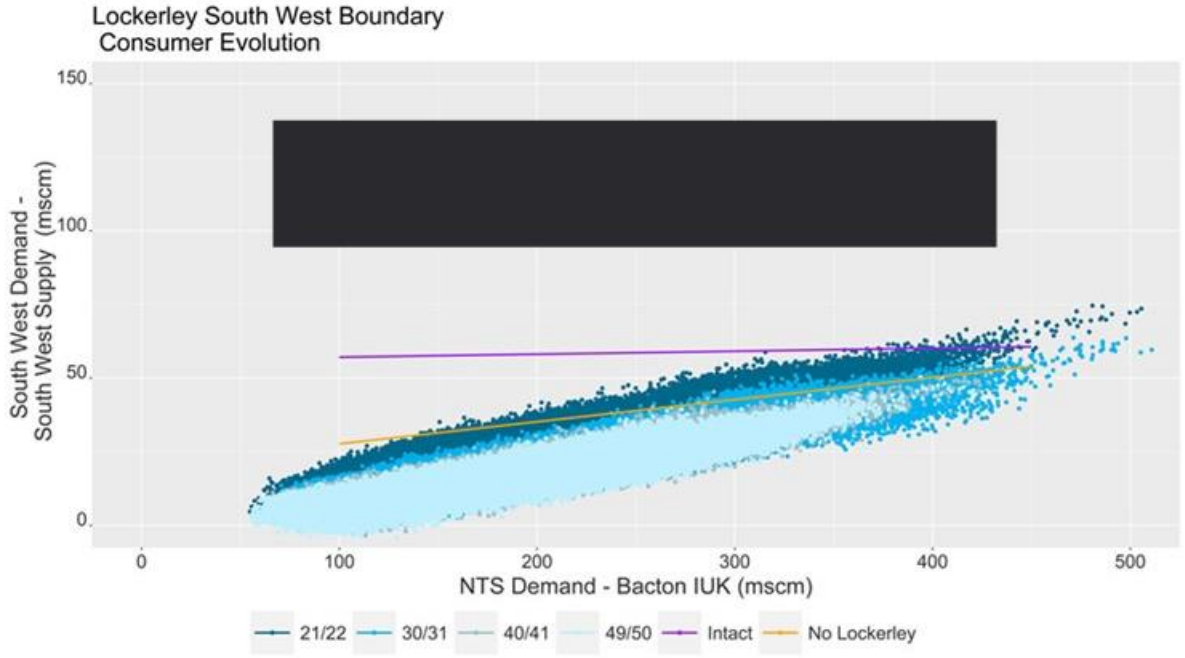


Figure E11: Ability to meet consumer exit requirements in the South West, with and without Lockerley (Two Degrees Scenario)

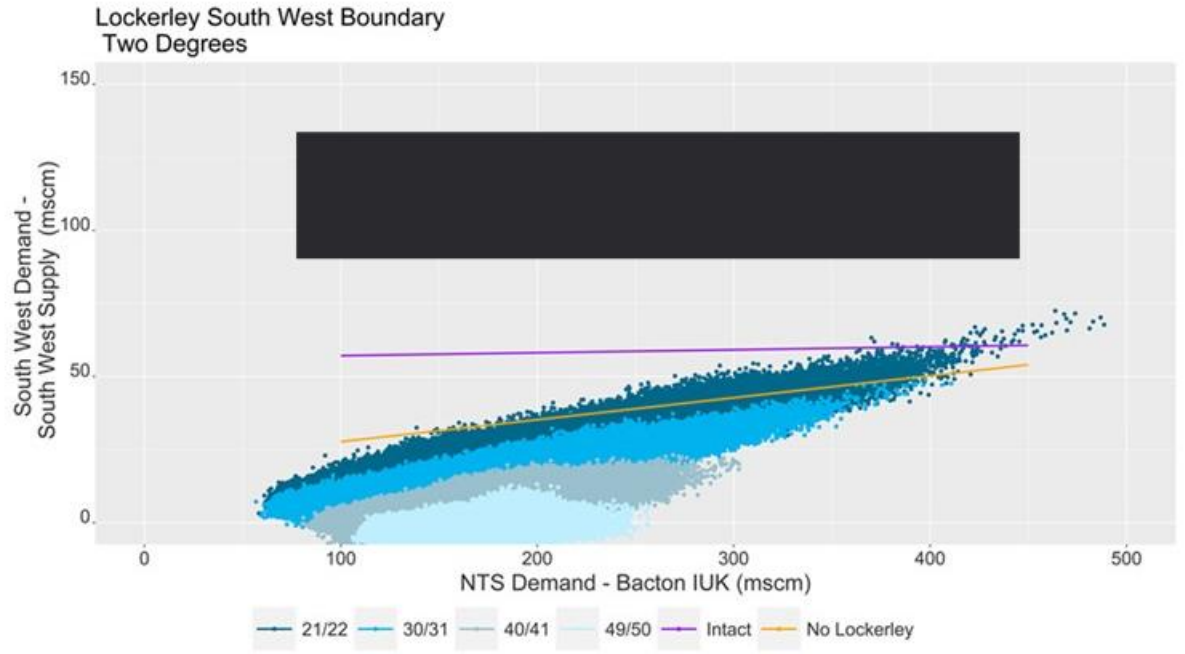


Figure E12: Ability to meet consumer exit requirements in the South West, with and without Lockerley (Steady Progression Scenario)

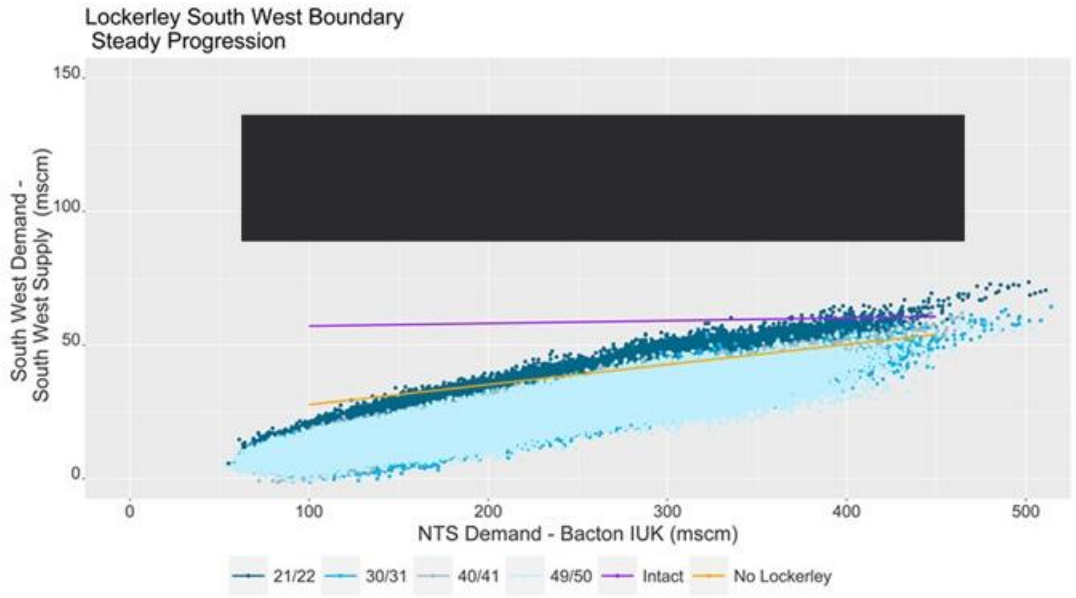
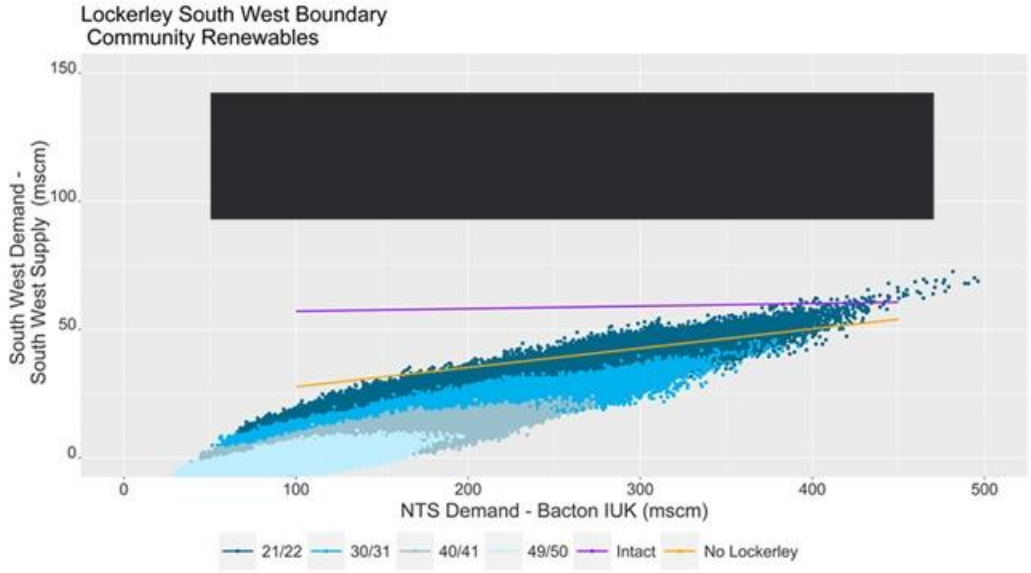


Figure E13: Ability to meet consumer exit requirements in the South West, with and without Lockerley (Community Renewables Scenario)



We have estimated the costs of managing these constraints under all four FES 2018 scenarios with without Lockerley, the results are shown in Figure E14.

Figure E14: Range of RIIO-2 constraint management costs

Conclusions

Our RIIO-2 business plan includes asset health and cyber security investments that will allow us to maintain compliance with the 1 in 20 licence obligation and ensure we can meet our customers' exit requirements in the South West. We have calculated (our median case) that without Lockerley compressor the additional RIIO-2 costs would be [redacted] (see Figure E15). We believe this median cost estimation to understate the actual costs as it uses actual OM contract prices for procurement of a smaller volume and hence procurement of a larger volume could be expected to require acceptance of higher tender prices.

Figure E15: Range of additional RIIO-2 costs without Lockerley compressor