Annex

A16.10 Wormington Compressor Engineering Justification Paper

December 2019

As a part of the NGGT Business Plan Submission

nationalgrid

Table of Contents

1. Executive Summary

1.1 This paper sets out our proposals at the Wormington compressor site to ensure sufficient network capability, to fulfil our customer and operational requirements, whilst also complying with the Medium Combustion Plant Directive (MCPD) emissions legislation. This justification paper supports the proposals in chapter 14 of the NGGT RIIO-2 business plan "I want to take gas on and off the transmission system where and when I want", and chapter 16 "I want to care for the environment and communities". This justification paper should be read in conjunction with the Compressor Emissions Compliance Strategy (CECS) in Annex A16.05 to the business plan.

1.2 Wormington compressor station is critical in transporting National Transmission System (NTS) gas entering through the Milford Haven terminal and utilisation is forecast to remain high over a wide range of network conditions and supply/demand scenarios to 2049.

1.3 Wormington compressor station comprises two Rolls Royce Avon compressors (Units A and B) and one electric-driven Siemens Variable Speed Drive (VSD) compressor (Unit C). Unit C is the lead unit on site but either units A and B operating in parallel with Unit C provide the maximum capability at Wormington, required when supplies from Milford Haven are high to avoid the risk of entry constraints. Units A and B also provide resilience when the electric-driven unit is not available due to planned or unplanned outages. The two Avon units are not compliant with the MCPD and therefore, a solution needs to be implemented at the site prior to the compliance date of 1 January 2030.

1.4 We need to maintain current levels of network capability at Wormington to meet stakeholder needs to take gas on and off the system as and when they want into the future. As UK continental shelf (UKCS) imports decline we expect supplies of LNG to increase in most scenarios, leading to higher utilisation of the existing capability at Wormington. There is an ongoing need at the site for 80mscm/d (based on the current requirements) and this has been confirmed through our network capability analysis.

1.5 The options considered for MCPD compliance were compared in a Cost Benefit Analysis (CBA). This compared the costs of installing and maintaining the proposed new units (the option with the highest positive Net Present Value (NPV)), together with estimates of constraint costs associated with the differing levels of capability and availability under each alternative option, to arrive at the lowest overall cost to consumers, see Table 1. We used the 2018 Future Energy Scenarios (FES), Steady Progression scenario in our analysis as our base case for the CBA with sensitivities being run against the other three scenarios, these are given in Table 2. Further detail is provided in Section 7.

1.6 The clear financial beneficial option from the CBA is to install two new, gas–driven compressor units (of similar rated power to the existing Avon units - approximately 15MW each) and decommission the existing Avon units at a cost of [redacted][1] in RIIO-2, ahead of 2030, following operational acceptance of the new units. This comes out as the most cost-effective option in the Cost Benefit Analysis (CBA) and is consistent with the Preliminary Best Available Techniques (BAT) assessment. This preferred option has a consumer saving of £455m compared to the counterfactual (see Section 6) in the central scenario. Without these new units there would be a risk that entry and exit capacities and/or 1-in-20 obligations would not be met if the existing electric drive unit is unavailable.

[1] Note that the CBA reflects project costs of [redacted] rather than [redacted]. This is because the CBA includes additional OPEX and asset health costs not covered by this specific RIIO-2 CAPEX investment.

Table 1: CBA Cost Inputs (2018/29 price base)

Cost (£m) – over 25 years from 2030	Option					
	0-Counterfactual (500hrs Units A&B)	**1- Two new units**	**2-One large unit**	**3a-SCR Units A and B**	**3b-SCR Unit A + 500hrs Unit B**	**Decommission 2029**
Operating costs over 25 years	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Constraint cost*	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Total CAPEX cost, including the below:	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
•Total installed costs	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
•Asset health costs over 25 years	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
•Decommissioning costs	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
First year of positive relative NPV	N/A	2039	2048	2045	2043	Never

Table 2: CBA Results – NPV relative to the counterfactual[2]

Short Name	Description	Central Case Steady Progression	High Sensitivity Two Degrees	Low Sensitivity Consumer Evolution	Additional Sensitivity Consumer Renewables
Option 0	0 - Counterfactual	£0m	£0m	£0m	£0m
Option 1	1 - Two new units	£455m	£1089m	-£42m	£188m
Option 2	2 - One new large unit	£146m	£410m	-£45m	-£147m
Option 3a	3a - SCR Units A and B	£328m	£910m	-£37m	-£115m
Option 3b	3b - SCR Unit A + Unit B 500hrs	£307m	£828m	-£16m	-£83m
Option 4	4 - Decommission 2029	-£1141m	-£2419m	-£61m	-£1543m

1.7 The cost is [redacted] in RIIO-2 for design and initiation of compressor build and [redacted] in RIIO-3 for completion of compressor build, in order that the site is fully available ahead of the MCPD deadline. Included is the cost of decommissioning the two non-compliant units in RIIO-3 of [redacted]. Delivery will be measured through a Price Control Deliverable (please see annex A2.01 for further information).

1.8 We have also undertaken a Preliminary Best Available Techniques (BAT) assessment on the options for MCPD compliance at Wormington. This established, stepwise assessment process is underpinned by an environmental cost-benefit analysis methodology, which draws together environmental and operational priorities to support decision making. The assessment was undertaken independently from the CBA analysis and is a different methodological approach; it however incorporated consistent assumptions on cost, investment cases and future gas supply predictions. The Preliminary BAT results were consistent with the CBA results as summarised in Section 6.

1.9 A Planning and Advanced Reservation of Capacity Agreement (PARCA) to increase entry capacity at Milford Haven is currently being assessed through a process independent of our RIIO-2 submission. The current analysis does not identify any requirement for additional compressor units at Wormington.

1.10 In the Preliminary BAT assessment, we assessed control system restricted performance as a means of meeting emissions compliance at Wormington. Where an Avon operating at full power emits a NOx level close to, or above, the 150mg/m3 legislative limit, it may be possible to permanently de-rate the Avon to limit the power in the control system and reduce NOx emissions from the unit. Although this could be

[2] Note that these calculated NPVs assume a capitalisation rate of 73.5% as set out in CECS (Annex A16.05). This capitalisation rate has now been updated, and therefore there may be a minor mismatch between quoted NPVs between this document and the associated CBA (Annex A16.11). Please note that this does not affect the final proposed option. The impact of the updated capitalisation rate is reflected in the CBA document.

a less expensive solution, implementing this technique will result in a change to the operating envelope of a unit. Wormington needs high-power operation to minimise Milford Haven risk and currently operates in breach of NOx emissions at high-power operation. Software models were used to predict performance of Avon units if they were restricted and used to supply site duty. The result of this analysis shows the potential for a significant amount of single engine useable compressor envelope being lost so that there would be insufficient compression available for the required movement of gas from Milford Haven under the various scenarios. In addition, it could also increase CO emissions, meaning it would not provide a reliable option in the medium to long term at Wormington. Therefore, this was not found to be a BAT solution and has consequently been discounted due to the operational capability required at Wormington.

1.11 In this paper, a 'Medium' unit refers to a unit of similar rated power to an existing Avon compressor unit – approximately 15MW. A 'Large' unit refers to a unit of similar rated power to an existing RB211 compressor unit – circa 27MW+.

2. Summary Table

The costs in this summary table and throughout the document are in 2018/19 price base.

Name of Project	Wormington MCPD		
Scheme Reference	TBC		
Primary Investment Driver	Compliance with MCPD legislation.		
Project Initiation Year	2019		
Project Close Out Year	2027		
Total Installed Cost Estimate (£)	[redacted] (two new units) [redacted] (decom of existing two units)		
Cost Estimate Accuracy	P50		
Project Spend to date (£)	£0.02m		
Current Project Stage Gate	4.1 – Establish Portfolio		
Reporting Table Ref	TBC		
Outputs included in RIIO-1 Business Plan	No		
Spend apportionment	**RIIO-1**	**RIIO-2**	**RIIO-3**
	£0.02m (spend to date)	[redacted][3]	[redacted]

3. Project Status and Request Summary

3.1 Existing levels of capability are required to be maintained at Wormington compressor site. National Grid is requesting funding at Wormington to ensure this capability is compliant with the Medium Combustion Plant Directive (MCPD). Two of the three compressor units on site are affected by the legislation. The most cost-effective and lowest risk option, to the consumer and National Grid, is to build two new compressor units across RIIO-2 and RIIO-3, then decommission the two MCPD non-compliant units thereafter. Further information on the MCPD and legislative drivers can be found in the Compressor Emissions Compliance Strategy (CECS) in annex A16.05 of the business plan.

3.2 The cost is [redacted] in RIIO-2 for design and initiation of compressor build and [redacted] in RIIO-3 for completion of compressor build. It is expected that at the end of the RIIO-2 price control the site will be at the completion of compressor build phase. Included is the cost of decommissioning of the two non-compliant units (A and B) in RIIO-3 of [redacted].

3.3 The project is currently in stage 4.1 (*'Establish Portfolio'*) of the Network Development Process (ND500) – a process aimed at defining and managing the project lifecycle from inception to closure, ensuring we meet minimum requirements for each project phase (for more information refer to CECS). We have so far carried out options assessment, CBA and Preliminary BAT assessment. Decommissioning of existing units A and B is planned to start in 2027 once the new units are fully operational.

3.4 Preliminary BAT assessment has been undertaken to support our CBA and to feed into this decision-making process. BAT analysis is an assessment of the available techniques best placed to prevent or minimise emissions and impacts on the environment. Options that were included in the Preliminary BAT assessment range

[3] See footnote 1.

from emissions abatement to new build solutions and are in line with those highlighted in Section 6 of this paper.

3.5 We have considered and costed several options for the site which would meet its operational requirements. Our recommended solution is supported by the CBA and BAT assessment which have considered investment costs for compressors; the constraints and contracts; and compressor running costs. It is also supported by stakeholder views around network capability and our environmental impacts; further information on this can be found in the CECS in annex A16.05.

3.6 Our assessment concluded it is more cost efficient to invest in new assets instead of managing operational restrictions commercially. The new units have been sized to meet the network capability needs of our customers and stakeholders in South Wales.

3.7 Related emissions legislation compliance work was not undertaken at Wormington site during RIIO-1. However, we undertook a number of other emissions compliance projects and learnings will feed into our RIIO-2 compressor emissions compliance projects. More information on this can be found in CECS annex A16.05.

4. Problem/Opportunity Statement

4.1 The purpose of this project is to achieve compliance with the MCPD at Wormington compressor site in order to provide the capability that the network requires in the most cost-effective way for end consumers. For more information on the MCPD, please refer to CECS in Annex A16.05.

4.2 Wormington compressor station comprises two Rolls Royce Avon compressors (Units A and B) and one electric driven Siemens Variable Speed Drive (VSD) compressor (Unit C) as shown in **Figure *1*** and **Table *3***. Unit C is the lead unit on the site. Units A and B are used if Unit C is not available, or if the flow through the site exceeds the capacity of Unit C (50 mscm/d). This typically occurs when entry flows at Milford Haven are high. Units A and B are non-compliant with MCPD.

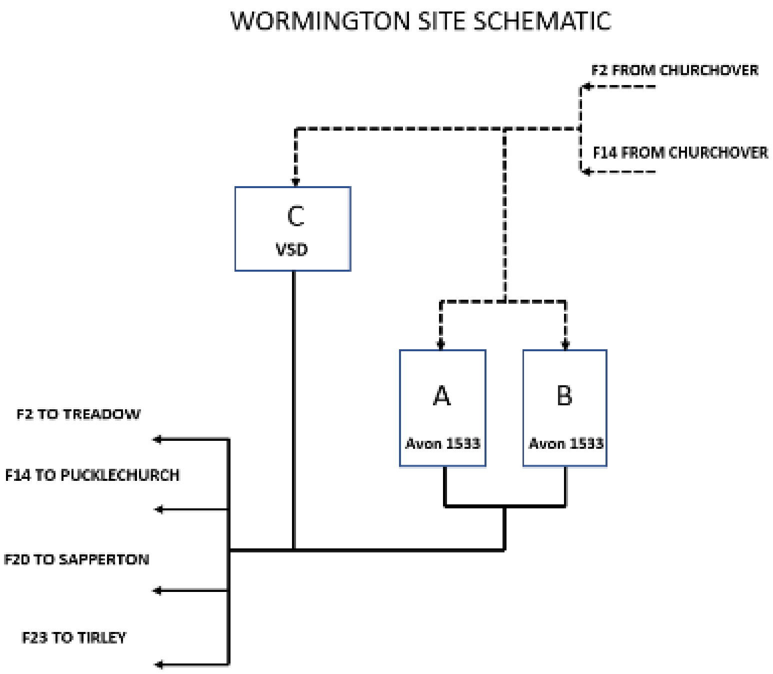

Figure 1: Wormington Site Schematic

Table 3: Existing assets summary

Unit	Manufacturer / Type	Fuel Type	Power Base (MW)	Installation Date	Minimum Operational Flow (mscm/d)	Nominal Capacity (mscm/d)	Maximum discharge pressure (barg)
A	RR/Avon	Gas	12.34	1989	13	40	75
B	RR/Avon	Gas	12.34	1990	13	40	75
C	Siemens Electric Variable Speed Drive (VSD)	Electric	15	2009	9	50	75

4.3 The use of compression at Wormington is strongly linked to the supply and demand levels in South Wales. Wormington compressor station has recently become critical in supporting NTS gas entering through the Milford Haven terminal and utilisation is forecast to remain high over a wide range of network conditions. Due to bi-directional flow capabilities, it is also used to support the extremities in Wales when demands are high and Milford Haven inputs are low.

4.4 Felindre and Churchover can provide some resilience to Wormington but they do not enable the same entry capability at Milford Haven terminal. Use of these sites instead of Wormington would lead to constraints on the network. The location of these compressor sites is illustrated in **Figure *2***.

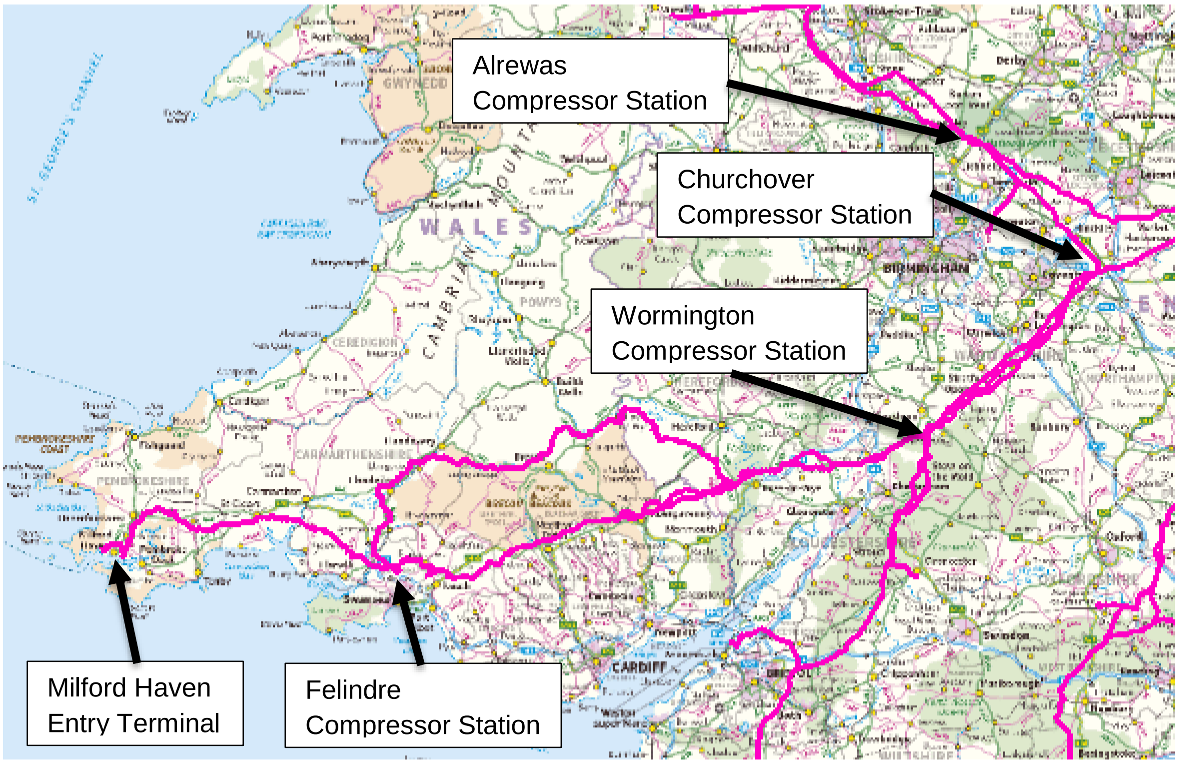

Figure 2: Location of Milford Haven terminal and related compressor sites

4.5 Units A and B operating in parallel provide the maximum capability at Wormington, particularly when supplies from the Milford Haven Liquefied Natural Gas (LNG) terminals are high. They also provide resilience when Unit C is not available due to planned or unplanned outages. As UK Continental Shelf (UKCS) supplies continue to decline, LNG supplies into the UK are forecast to increase in most FES scenarios. Therefore, the requirement for compression at Wormington is forecast to increase over time, and consequently the importance of resilience capability at Wormington will also increase, as shown in **Figure 3**. This shows a sustained requirement for running hours above the derogated limit of 500 hours beyond 2030.

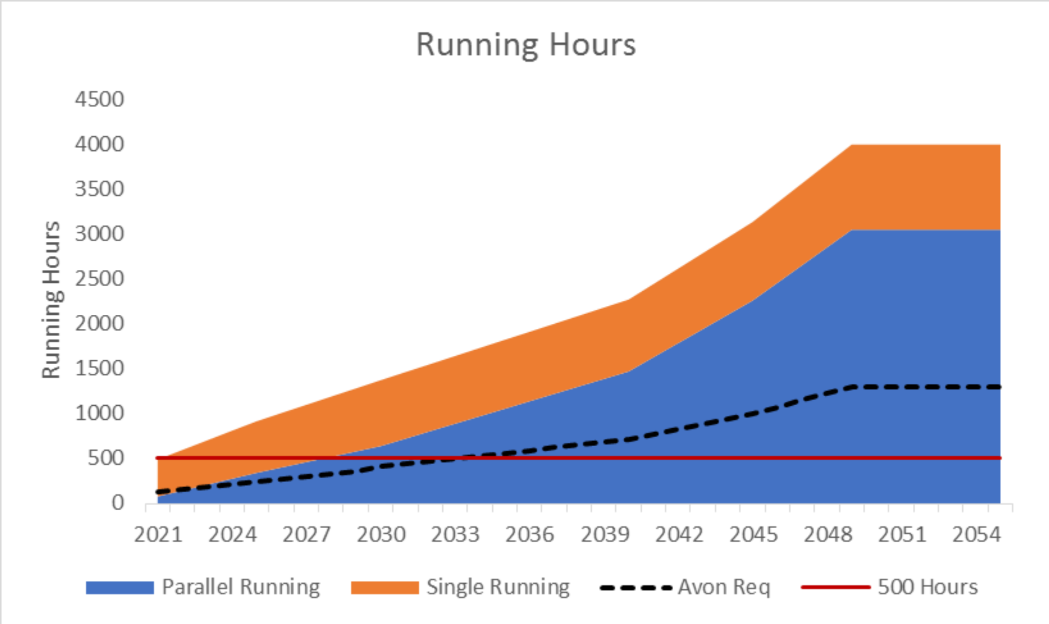

Figure 3: Forecast running hours at Wormington compressor station

4.6 A PARCA to increase entry capacity at Milford Haven is currently being assessed through a process independent of our RIIO-2 submission. The outcome of the PARCA process is expected to be known in mid-2020.Without the proposed investment, there would only be one unrestricted compliant unit on site, the VSD. The derogated Avons (designed to run remotely in parallel) would give limited resilience. There is also a requirement for additional units when flows are above the capability of the VSD. The electric unit is not designed to operate in parallel with the Avon units, but with an engineer on site it can be used to provide resilience if either Avon unit were not available. Insufficient capability and availability of compressors on the site, would lead to restrictions at Milford Haven terminal, and consequently high constraint costs for industry and potentially higher gas costs for consumers.

4.7 Our proposal is to build two new, gas–driven compressor units (of similar rated power to the existing Avon units) on adjacent, unused land within National Grid boundaries at Wormington, sized to meet the capability required for current and future customers. Building on adjacent land allows the existing compressor units to be used until the new units have been operationally accepted. This option provides an optimal balance between investments and operational costs, and unit availability and support to a wide range of Milford Haven and South West flows, as measured by the CBA. Once the new units are in service, Avon Units A and B would be decommissioned. For more information on how the CBA was carried out, please refer to CECS in annex A16.05.

4.8 Stage gates in the ND500, ensure we meet minimum requirements for each project phase (for more information refer to CECS). The milestones are based on our current view of investment in new compressors. Milestone dates have been informed by scheduling of this project against other planned investment work, which has identified the opportune time to begin the Original Equipment Manufacturer (OEM) design and build phase at Wormington as 2022 with operational acceptance and project closure in 2027. Therefore, the key milestones have been estimated around this time scale, as shown in **Table 4**. More detail is provided in **Table 36** in Section 8.7.

Table 4: Key Milestone Dates

New Build			
Cycle	**Network Development Stage Gates**		**Indicative Dates** **Wormington**
Pre-FEED Stage 4.0 and 4.1	**T0 – T2**	• Generation of Need Case • Accept Need Case • Initial Sanction • Define Strategic Approach and Outputs Required to Deliver • GT Handover to Delivery Unit	April 2019 – June 2021
FEED Stage 4.2	• **F2** **F3**	• FEED Sanction and Feasibility Sanction • Includes BAT assessment and Compressor Machinery Train selection • Agreement to Proceed to Conceptual Design • Conceptual Design Sanction and Sanction of long lead items	June 2021– June 2022
Tender Award Stage 4.3	**T4**	• Scope Freeze	September 2023
Project Execution Stage 4.4	• **F4** • **T5**	• Detailed Design AND Build Sanction • DDS Challenge, Review and Sign off Maintenance Requirements Identified	• September 2023 • June 2025
Acceptance Stage 4.5	• **T6** • **T5**	• Post Commissioning Handover to GT • Operational and Maintenance Complete or Planned (Operational Acceptance) • Project Closure	• June 2026 • March 2027

4.9 Project success will be confirmed by operational acceptance of the two new units, safe and full decommissioning of the two Avon units, meeting customer demands throughout construction and compliance with MCPD legislation as well as the project completed to time, quality and cost. Delivery will be measured through a Price Control Deliverable. Please see Annex A2.01 for more information on this.

4.10 Challenges to this project are summarised below and elaborated further in **Table *37***:

- Outages;
- Appropriate flows for commissioning;
- Land; and
- Contracts.

4.11 Circumstances that would lead to a change in the need or option for this project are:

- Changes in supply and demand patterns beyond FES 2018;
  - Investment or new discoveries in UK gas production (UKCS, Shale and green gas) reducing LNG important dependency.
  - Changes in the interconnectors' operating models or services that either increase or decrease supplies from Europe.
  - UK moving towards a Hydrogen market sooner than 2030 and on a bigger scale, depending on whether this leads to a direct reduction or significant increase in gas demand in Wales.
  - Closure of storage sites that are no longer economic requiring additional LNG to balance supply and demand.
  - Changes in Gas Safety (Management) Regulations (GS(M)R) requirements allowing entry of lower quality gas from UKCS fields and the

blending of Hydrogen. This would reduce UK import dependency and lower the requirement for LNG.
    - Changes in geographical demand relative to today due to areas adopting different technologies for heating. This could reduce compression requirements in some areas as they adopt cleaner fuels for heating or increase it for areas with access to Carbon Capture Utilisation and Storage (CCUS) schemes.
    - How the government implements the findings of the Climate Change Act 2008 (2050 Target Amendment) from May 2019;
        - Use hydrogen and electrification to replace fossil fuel.
        - Use electricity/hydrogen for transport without an interim biofuel step.
- Changes in European markets;
    - Conversion of European power stations to gas which could reduce imports through the interconnectors and increase UK dependency on LNG.
    - Europe and Norway move to a Hydrogen based market at different timescales to the UK. This reduces the flows through the interconnectors and increases the UK requirement for LNG to meet demand.
    - New pipelines from Russia reducing LNG requirements in other parts of the world results in additional cargoes to the UK.
- Changes in the global LNG markets;
    - Changes in world markets could either reduce or increase the amount of LNG coming to the UK. Historically the Asian markets have influenced how much LNG comes to the UK e.g. the Japanese tsunami in 2007
- Outcomes from BAT assessment and tender which may influence the choice of technology, with alternative units being provided by OEMs such as proposed units offering hydrogen compatible compression.

Related Projects

4.12 Projects related to Wormington MCPD:

- A PARCA was recently signed to increase entry capacity at Milford Haven. This is being considered separately to the RIIO-2 submission. We have investigated potential impacts of the various options of this PARCA and our proposals for Wormington are valid for all outcomes. Furthermore, we anticipate that if it is taken forward this could further utilisation of Wormington.
- Technology investments (i.e. cyber upgrades, asset health etc.).

Project Boundaries

4.13 The scope of this project is for costs associated with the delivery of MCPD compliance only. For Wormington, these are costs associated with building two new units and decommissioning two non-compliant units. Other costs such as ongoing asset health costs and operational running costs are included in the CBA, although we are not requesting funding through this paper.

5. Project Definition

Supply and Demand Scenario Discussion and Selection

5.1 To fully assess the project, a network assessment and a risk and constraint assessment was carried out. The network assessment was done to define the capability boundaries, for more information refer to CECS. The boundaries feed into the constraint and risk assessment to define the associated costs.

5.2 We have used the Steady Progression scenario from the FES 2018 as the base scenario for this proposal as it provides an appropriate central case for Wormington's expected use. Wormington specific sensitivities were defined and carried out as part of the assessment which involved Milford Haven Entry.

Key flows and boundaries

5.3 To assess the impact of increased flows at Milford Haven we assessed how supply and demand across the four FES scenarios could change in the future; the changes in demand can be seen in **Figure 4** and **Figure 5**.

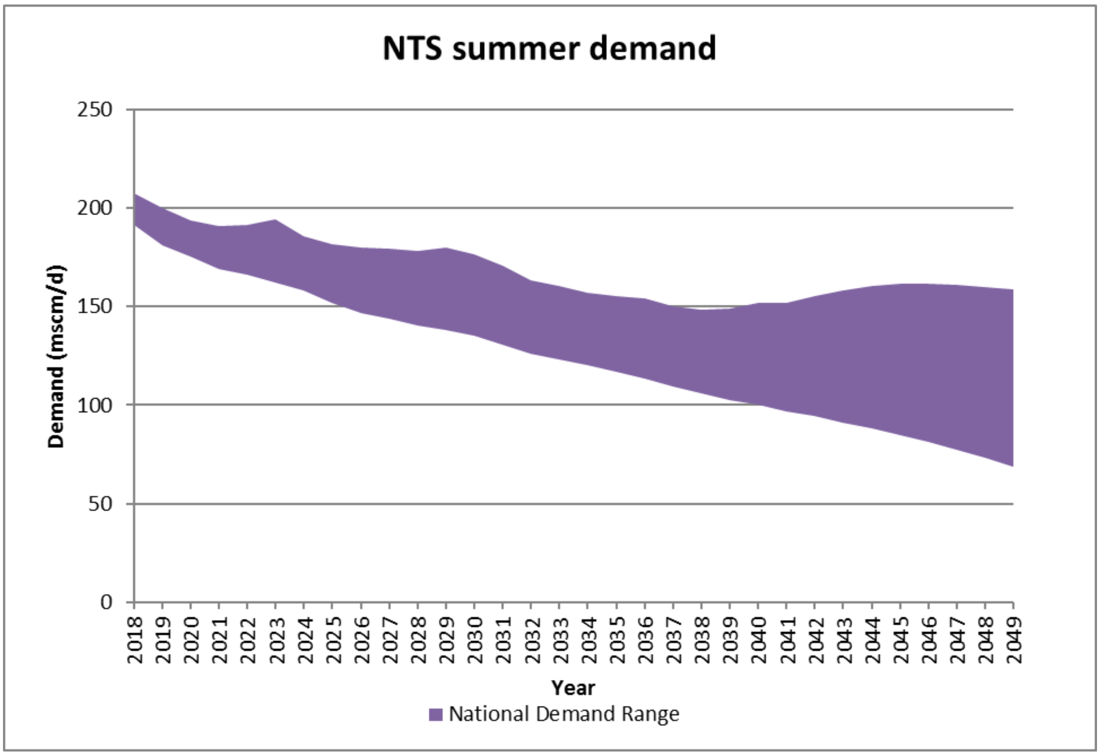

Figure 4: FES 2018 National summer demand

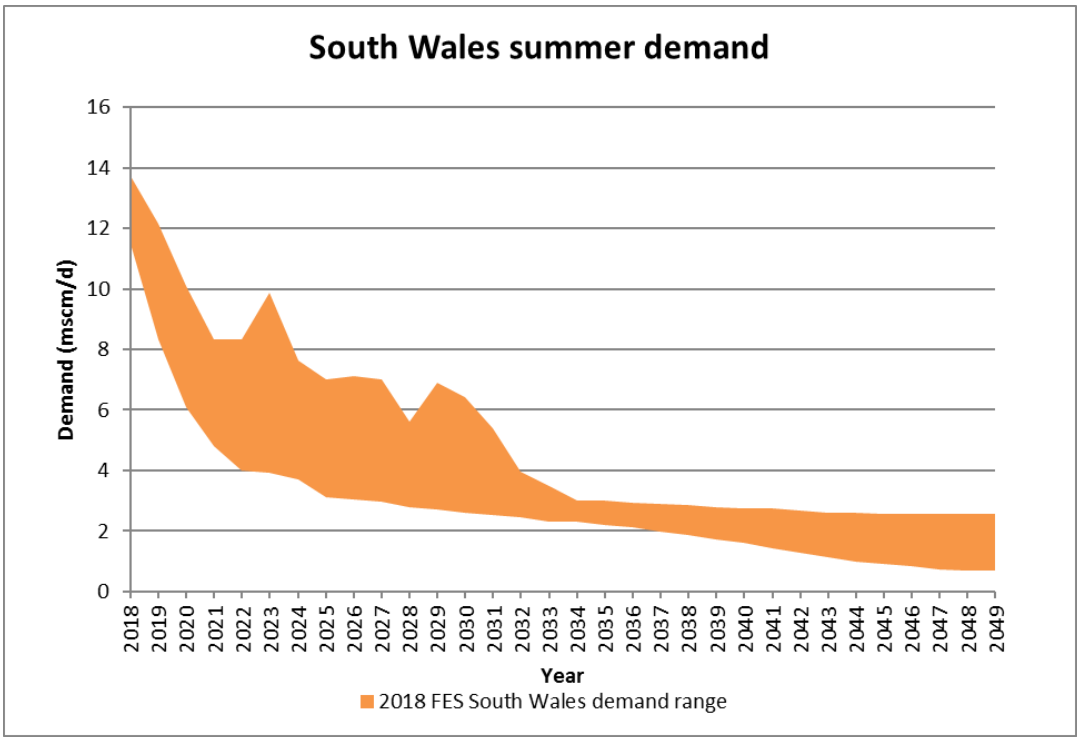

Figure 5: FES 2018 South West summer demand

5.4 **Figure 4** shows that national demand decreases in all four scenarios. **Figure 5** shows how the demand between Milford Haven and Churchover (South Wales demand) is reducing and could be as much as 80% lower (10 mscm/d) by the 2030's than it is today. This means that in the future the additional 10 mscm/d will need to flow through each of the compressors sites at Felindre, Wormington and Churchover towards the areas of demand, even if supplies stayed at the same level as they are today. Leading to an increased requirement to operate these compressors.

5.5 Over the next 20 years, UKCS supplies will continue to decline. In some scenarios, this supply is replaced through the development of other indigenous sources, such as shale gas, biomethane and bio-substitute natural gas (bioSNG). Some of these may connect either to the NTS or to the distribution networks. In three out of four scenarios, these are insufficient to meet demand and therefore imported gas will become more important. These imports could be from continental Europe or as LNG.

5.6 The highest LNG case is the Two Degrees scenario in which gas demand increases to support hydrogen production, increasing demand for imports including LNG. In this scenario, we would see LNG supplies double by the end of RIIO-2 and be five times the level seen today by 2030. The lowest LNG case is the Consumer Evolution scenario in which high volumes of domestic shale gas production reduce the need for imports, which are mostly sourced from Norway. In this scenario, we would see LNG supplies at a similar level to today by the end of RIIO-2. **Figure 6** shows the yearly LNG supply range across the four FES scenarios under both a high LNG or high Continental Europe supply scenario.

Figure 6: FES 2018 Milford Haven flow range

5.7 Wormington is typically the first site to be operated to support gas entering at the Milford Haven terminal. If the entry levels increase, they will have a direct impact on the number of run hours for the units on site.

5.8 To provide the maximum entry capability at the terminal, the two Avon units operating in parallel are required. The electric unit was not designed to operate in parallel with the Avon units. It is assumed that the new units would be designed to work remotely in parallel with the existing unit. This would provide valuable additional resilience in the capability at Wormington.

5.9

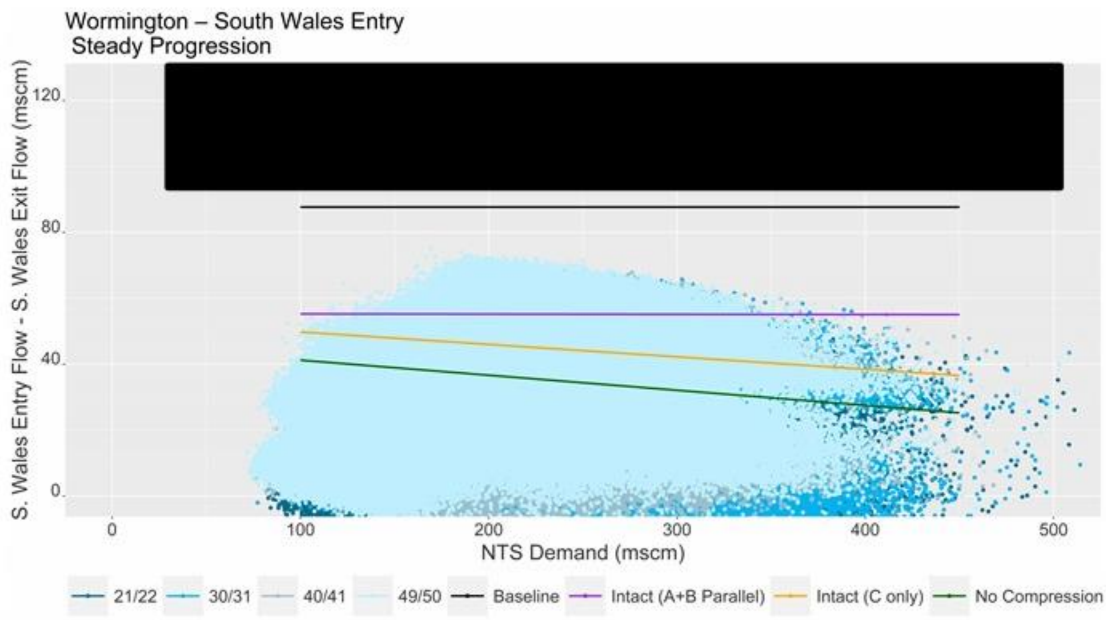

Figure 7 to **Figure 10** show the risk of constraints under different asset availability assumptions. Each dot on the chart is associated with one day in that year and for every day there are 1000 alternative supply and demand patterns. The different coloured dots are for different years showing how we expect supply and demand patterns to change over time. The table at the top of the chart shows how the number of dots above a line translates into constraint days. For instance, in

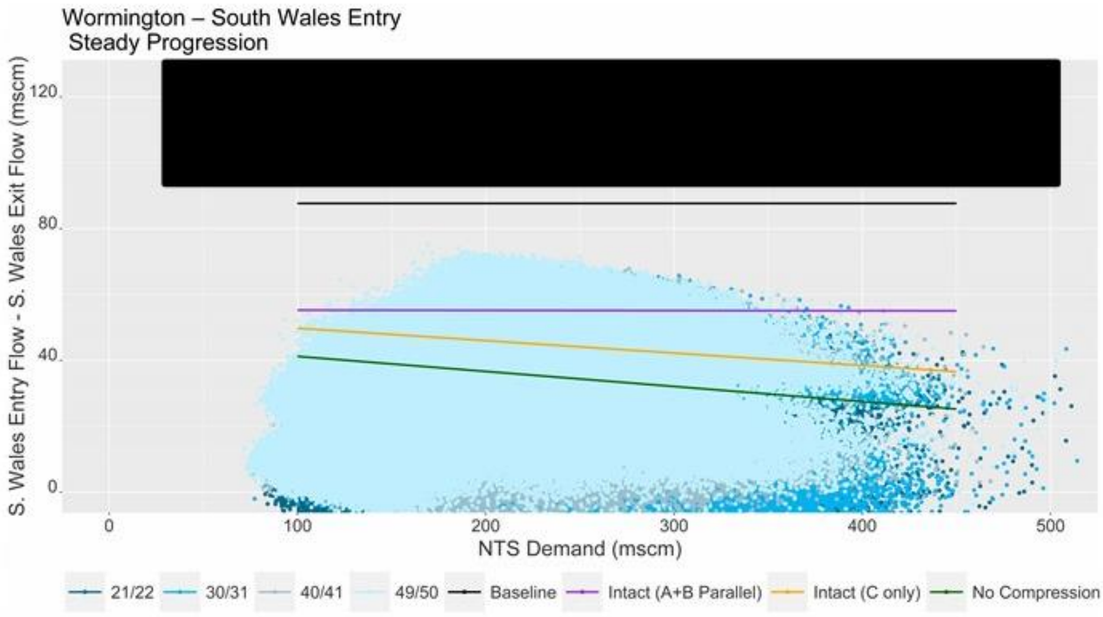

Figure 7 the green row of the table "Intact (no units)" shows that with no compression at Wormington we would expect an average of 80 days of constraints in 2030/31.

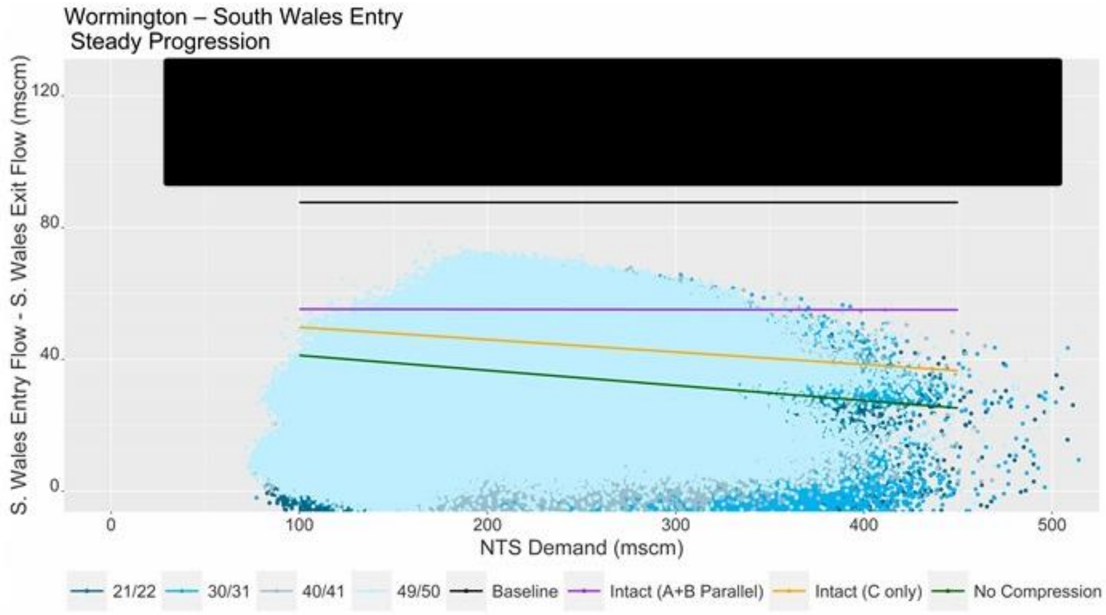

Figure 7: Network entry capability at Milford Haven (Steady Progression 2018)

5.8

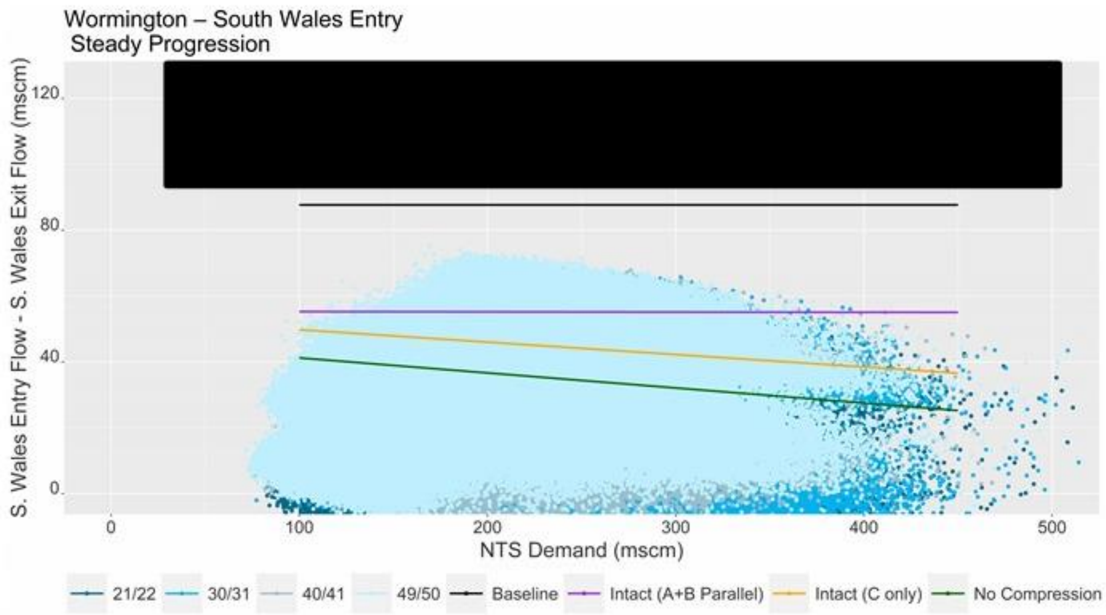

Figure 7 shows how the entry capability of the network in South Wales is reduced if Avon units are not available to operate in parallel, and capability is limited to the throughput of the electric VSD unit. It compares the capability of Wormington Compressor Station to move gas away from the terminal against our forecasts of entry supplies through the Milford Haven terminals and exit demands between the terminal and Churchover Compressor Station under the Steady Progression scenario (FES 2018). Three scenarios are considered:

i. Avon Units A and B operating in parallel (the purple line).

ii. VSD Unit C only (the orange line).

iii. No units available (the green line).

5.9 This illustrates the significant potential disruption to customer entry flows when Units A and B are not available to operate in parallel. This could be due either to planned or unplanned outages, or due to limits on running hours if a derogation has been applied. The entry capacity constraint costs associated with this reduction in capability have been included in our CBA assessments of the options for Wormington.

5.10

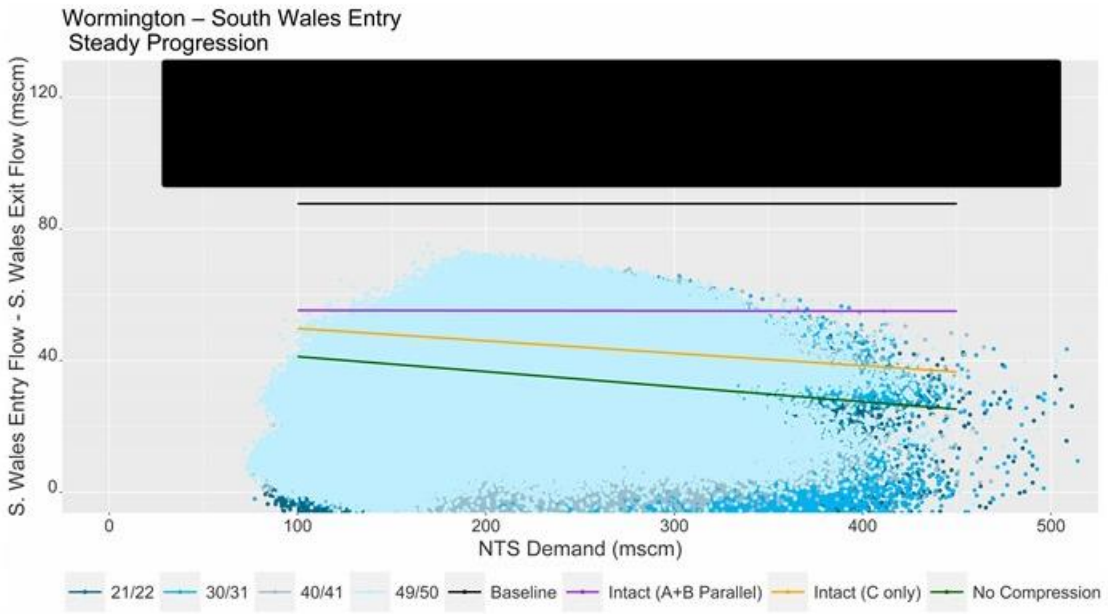

Figure 7 also shows that we are currently unable to support baseline level flows during the summer months and how the risk of constraints increases in the later years even with Units A and B available. This is caused by network constraints further into the network than Wormington compression station and is outside the scope of this paper.

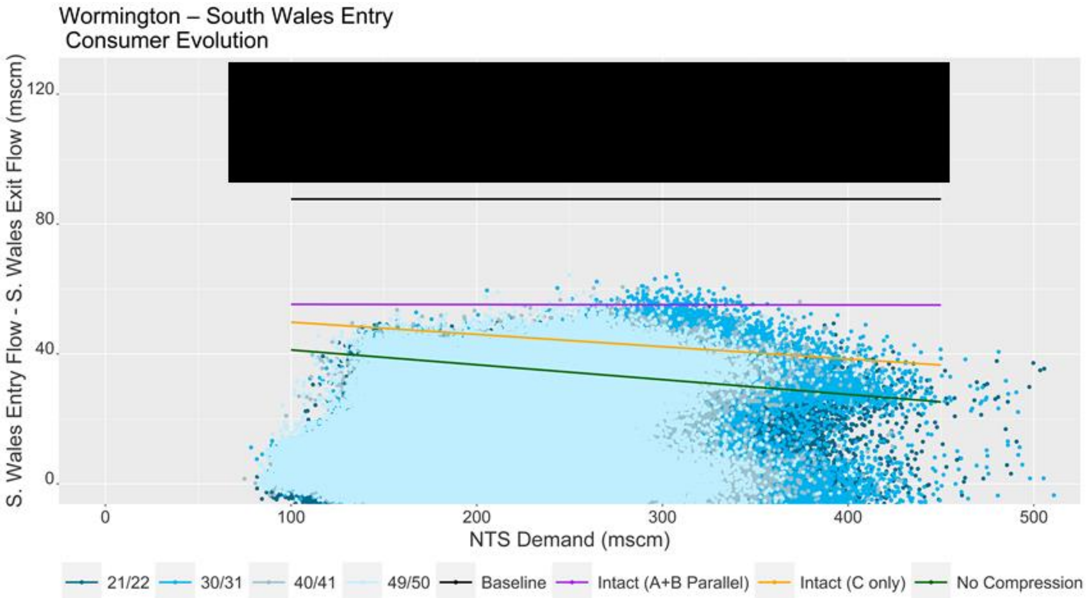

Figure 8: Network entry capability at Milford Haven (Consumer Evolution 2018)

5.11 **Figure 8** compares the network entry capability with our forecasts of entry supplies through the Milford Haven terminals under our low case, the Consumer Evolution scenario (FES 2018). The chart illustrates that there is still the potential for disruption to customer entry flows in this scenario, if Units A and B are not available to operate in parallel.

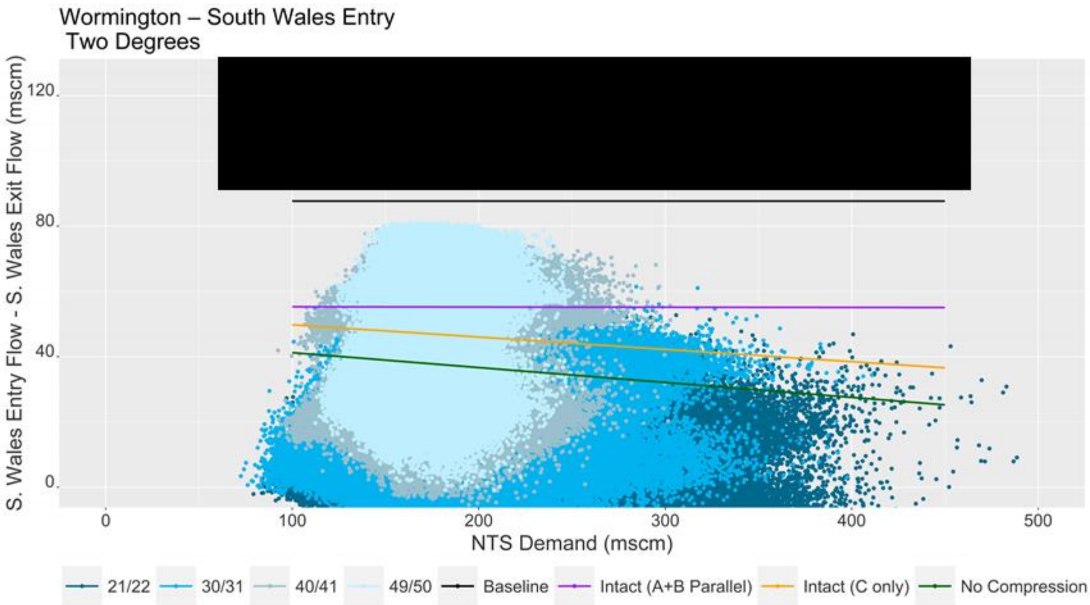

Figure 9: Network entry capability at Milford Haven (Two Degrees 2018)

5.12 **Figure 9** compares the network entry capability with our forecasts of entry supplies through the Milford Haven terminals under our high case, the Two Degrees scenario (FES 2018). The chart illustrates that there is an increased potential for disruption to customer entry flows in this scenario, if Units A and B are not available to operate in parallel.

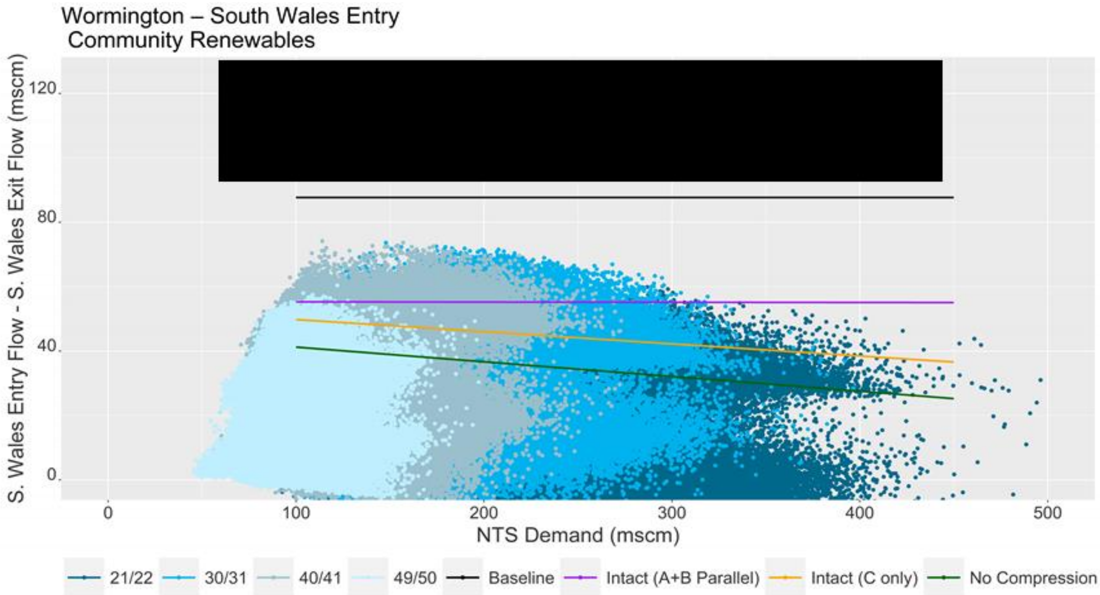

Figure 10: Network entry capability at Milford Haven (Community Renewables 2018)

5.13 **Figure 10** compares the network entry capability with our forecasts of entry supplies through the Milford Haven terminals under the final scenario, Community Renewables (FES 2018). The chart illustrates that there is an increased potential for disruption to customer entry flows until 2040/41, if Units A and B are not available to operate in parallel.

South Wales Exit

5.14 When flows entering the network at Milford Haven terminal are low and demand is high in South Wales, Wormington can be used to support the required exit pressures and ensure supply and demand remains balanced in the area.

5.15 The preferred site to support the South Wales demands would be Churchover[4] due to the need to support Assured Operating Pressures in the West Midlands. Wormington can provide resilience if Churchover is not available and pressures can be re-negotiated with the GDN. Wormington Unit C would be the first choice for resilience, with Units A and B providing secondary resilience if Unit C is unavailable. Given the low likelihood of Units A and B being required in this scenario, it has not been included in the CBA.

South West Exit

5.16 Wormington can support exit pressures in the South-West along feeders 14 and 20 including power stations close to the River Avon, and the extremity of the system at Choakford. Without the compression at Wormington being available, most of the gas needs to be transported via a different route along the southern feeder. This scenario has not been included in the CBA at this stage due the strength of the need case to support Milford Haven entry flows.

[4] Please refer to 2

Current Operation

5.17 Wormington compressor station is critical in supporting NTS gas entering through the Milford Haven terminal and utilisation is likely to remain high over a wide range of network conditions as shown in

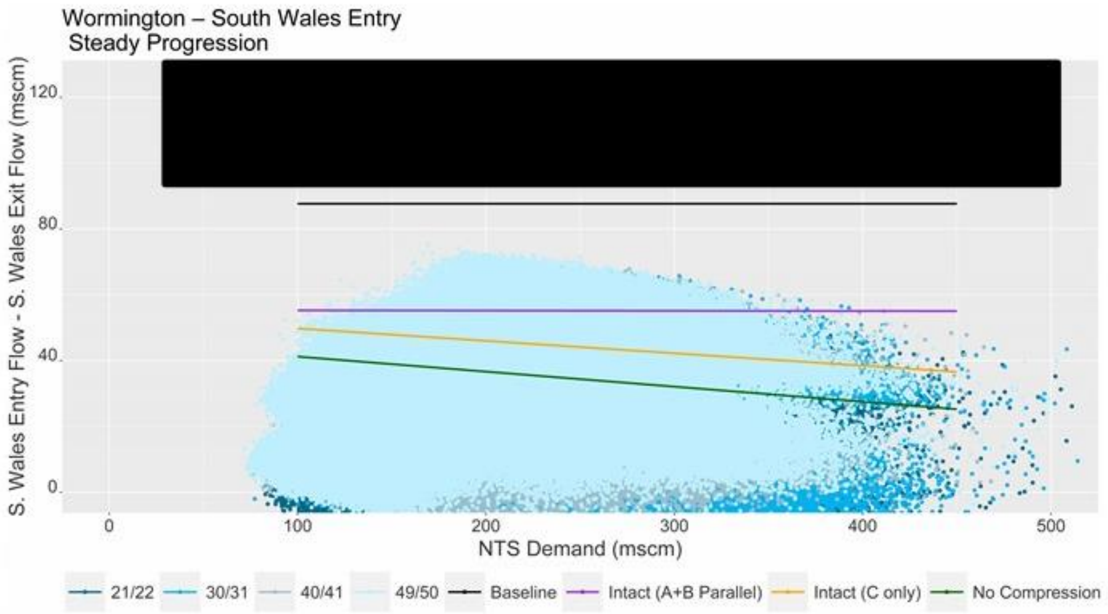

Figure 7 to **Figure 10**. Due to bi-directional flow capabilities, it is also used to support the extremities in Wales when Milford Haven terminal inputs are low and Churchover is on outage.

5.18 The electric drive (Unit C) has become the lead unit onsite since its commissioning, accounting for most of the run hours. The unit is limited to 50 mscm/d and would not be able to meet obligated entry levels from the Milford Haven terminal on its own, and currently relies on parallel operation with the exiting Avons.

Compressor Utilisation

5.19 The annual (financial year) running hours of the three units are shown in **Table *5***. Changes in the level of run hours are due to changes in the supply level at Milford Haven terminal. For example, running hours in 2015/16 were associated with higher supplies, leading to a need for compression to move gas out of South Wales; whereas the high run hours in 2017/18 were associated with low supplies requiring Wormington Unit C to support South Wales demand. There were fewer running hours in 2018/19 with entry levels at Milford Haven not exceeding the capability of Unit C.

Table 5: Run hours – as reported in the Regulatory Reporting Pack

	Individual Unit Running Hours *(financial year)*					
	2013/14	**2014/15**	**2015/16**	**2016/17**	**2017/18**	**2018/19**
Wormington Unit A	27	32	256	145	12	11
Wormington Unit B	58	27	67	190	23	19
Wormington Unit C	1,048	1,381	1,873	968	2,121	788

Total	1,132	1,441	1,966	1,303	2,155	818

Monthly Run Hours

5.20 The use of compression at Wormington is strongly linked to the supply and demand levels in South Wales. ***Figure 11*** shows the monthly usage of Wormington over the past five years.

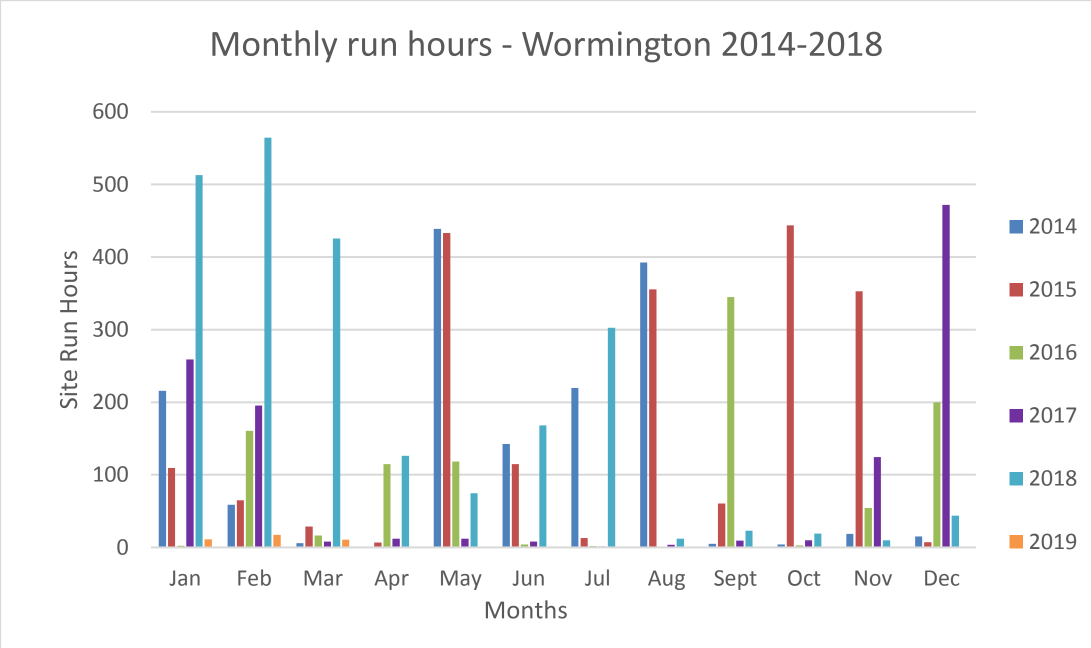

Figure 11: Monthly Run Hours for Wormington Compressor Station (2014 – 2019)

5.21 There are months with high run hours which are due to a change to either high or low supply flows at Milford Haven terminal as described above. It is clear from the historical run hours that Wormington utilisation varies throughout the whole year.

5.22 The high run hours during the winter periods are typically when Wormington is utilised to support South Wales Exit. Gas is pumped into Wales when demand is higher, and Milford Haven supplies are low. The high run hours during the summer and spring months are due to higher levels of LNG supplies and Wormington is required to move gas away from South Wales.

Compressor Availability

5.23 We calculate compressor availability based on historical averages for each compressor type on the network. This calculation uses the number of trips per 1,000 hours in the last five years. We then estimate the expected outage duration for each trip based on our operational experience, giving the availabilities shown in **Table 6**. These are applied to the individual options in the CBA to inform the level of availability each provides and the subsequent cost of constraints. Please refer to CECS for more information on the assumptions that have been made regarding the compressor availability.

Table 6: Compressor Availability

Unit	500 hrs	>500 hrs

AVON 1533	85%	73%
VSD	96%	91%
New 15MW Gas Unit	97%	88%

Project Scope Summary

5.24 The recommendation is for two new units at Wormington to give maximum resilience and availability and to support a wide range of Milford Haven and South West flows. **Table 7** provides the project scope summary.

Table 7: Wormington Project Scope Summary

New build at Wormington	
Location	Wormington Compressor Station
Number of units	Two medium sized units
Size of units	Medium – circa 15MW
Type of unit	Gas Turbine (GT)
Scope boundaries	The scope of this project is for costs associated with the implementation of the MCPD only. For Wormington, these are costs associated with building two new units, and decommissioning two non-compliant units.
Station design discharge pressure	75 barg
Station suction trip pressure	38 barg
Availability required	The optimum level of availability is determined by the selected option (98.4% for 2 x new units running in parallel, and 100% single unit running in 2030)

6. Options Considered

Option Summary

6.1 The options we considered cover a range of commercial, regulatory and physical solutions to provide capability for all compressor units captured by MCPD. These options are laid out within the CECS in Annex A16.05. In all cases the counterfactual is to retain all non-compliant units which would be limited to 500 hours (derogated) from 1 January 2030.

6.2 An independent GIS screening exercise was undertaken, with input from National Grid, to identify potential parcels of land for the new Wormington compressor units considering constraints imposed by separation and safety distances, buried feeders and key infrastructure. HSE consultation distances to sensitive neighbourhood receptors and other environmental and statutory constraints were also considered. A potential new location has been identified within the land boundary outside the existing security fence. This output is subject to preliminary engineering review and appraisal and initial environmental constraints surveys.

6.3 A high-level summary of all options considered for Wormington is shown in ***Table 8*** below.

Table 8: Full Options List

Standard options for Avon	Assessed	In which Option and on which compressor units Or Why option wasn't considered
500-hours Derogation (counterfactual)	✓	Option 0 (Units AB) Option 3b (Unit B)
Two new 15MW Gas Turbine Compressors, decommission Avons once new units are operational.	✓	Option 1
Control system restricted performance*	x	Due to operational requirements of this site, it is not a viable option because of the impact of reducing the capability of the units and the site thereby increasing the likelihood and impact of risk to National Grid. Preliminary BAT analysis rules out this option for Wormington.
One new 15MW Gas Turbine Compressor, decommission Avon once new unit is operational.	x	High flows from Milford Haven require parallel running of smaller 15MW units and one unit in combination with a derogated unit would use >500hrs.
One new 30MW Gas Turbine Compressor, decommission Avon once new unit is operational.	✓	Option 2
Emissions abatement (Selective Catalytic Reduction (SCR)) on Avon	✓	Option 3a (Units AB) Option 3b (Unit A)
Disconnect and Decommission Avon prior to 2030**	✓	Option 1 (Units AB) Option 2 (Units AB)
Two new 15MW Electric Drive Compressors, decommission Avons once new units are operational.	x	Wormington's lead unit is an electric drive; therefore, additional electric drives are not considered for network security and reliability reasons. Our principle is that backup to electric drives will be through gas turbine units for network security and continued supply in the event of loss of electricity supplies***.
One new 30MW Electric Drive Compressor, decommission Avon once new unit is operational.	x	
Commercial contracts to manage constraints and to ensure compliance with 1-in-20 obligations	x	No specific 1-in-20 requirement, all constraints related to entry.

* Control System Restricted Performance is where an Avon operating at full power emits a NOx level close to the 150mg/m3 legislative limit, it may be possible to permanently de-rate the Avon to limit the

power in the control system and reduce emissions from the unit Please see CECS Annex A16.05 for more information.
**between 2024 and 2031 depending on site, unit and option
***Refer to CECS for more information.

6.4 Costs have been compiled internally by eHub, National Grid's Estimating and Cost team and by our Compressor team. Compressors, abatement and decommissioning costs are based on previous project experience. National Grid operational expenditure (OPEX) and asset health, including ongoing abatement spend, is calculated on a site-specific basis from historical data. We have assessed our costs used against Ofgem guidance and confirm the following view.

Cost realised from RIIO-1 actuals	Cost forecast based on competitive process or previous tenders	External Benchmarking	Proposed Price Control Deliverable mechanism
Yes	Yes	No	Yes

6.5 Cost estimates used in the CBA include a sensitivity range associated with P50. Refer to CECS for more information on where these costs came from. Constraints and contracting costs are calculated using FES. The pricing methodology is referenced in **Table *32***.

6.6 We have developed a set of additional criteria to assess options alongside the CBA, which is summarised below in **Table 9**. More information on how this is used can be found in the CECS (annex A16.05)

Table 9: Option Criteria

Criteria	***Description***				
Can we meet FES predicted Entry levels?	Cannot meet FES Entry levels.	Meets FES Entry levels in less than 50% of the scenarios.	Meets FES Entry levels in 50% or more of the scenarios.	Meets FES Entry levels in all scenarios.	Increased Entry levels above predicted FES levels.
Can we meet FES predicted Exit levels?	Cannot meet FES Exit levels in all scenarios.	Meets FES Exit levels in less than 50% of the scenarios.	Meets FES Exit levels in 50% or more of the scenarios.	Meets FES Exit levels in all scenarios.	Increased Exit levels above predicted FES levels.
Does this option represent an appropriate level of resilience on the network?	Does not provide resilience for the loss of largest credible unit(s) at the station.	Reduces resilience considering the loss of units at interacting stations, where the affected units are currently next in line.	Reduces resilience for the loss of units at interacting stations, where the affected units are not currently first in line.	Provides similar level of resilience as the existing situation.	Increases the resilience of the network.
Does this option allow National Grid to retain current capability?	Will reduce capability and impact how the NTS is currently used.	Capability reduced to a level insufficient to meet sold capacity and/or FES levels.	Capability reduced to potentially be insufficient to meet sold capacity and/or FES levels.	Sufficient cap ability to meet sold capacity and/or FES levels.	Increased capability to meet sold capacity and/or FES levels.
Does this option allow the network to be operated in sensitivities beyond FES?	FES cannot be met.	Significantly reduces capability to exceed FES.	Reduces capability to exceed FES.	Provides similar capability as the existing situation to exceed FES.	Enhances the ability over the existing situation to exceed FES.

Option Descriptions

6.7 Each option considered for Wormington comprises asset actions, commercial actions, benefits and risks.

Option 0 – Counterfactual (500-hours Derogation)

6.8 The counterfactual option is the option that minimises RIIO-2 and RIIO-3 investment in new build units or asset decommissioning whilst meeting compliance with legislation. This option removes the need for new MCPD driven asset investment and utilises the existing units.

6.9 The cost breakdown of the option is given in **Table 10.**

Table 10: Counterfactual option cost

Option Title	Operating cost (£m)	Constraint cost (£m)[5]	Total Installed cost (£m)	Asset Health cost (£m)	Decommissioning cost (£m)	Cost accuracy
0 - Counterfactual 500-hours	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	P50

Asset actions

6.10 This option maintains Avon Units A and B until 31 December 2029 and places them on 500-hours derogation from 1 January 2030.

Commercial actions

6.11 There are no commercial contracts required to ensure compliance with the 1-in-20 design standard for the counterfactual option. Network Entry constraints would be managed using existing tools, and these constraint costs would be expected to be significant once the derogations kick in from 2030.

Benefits

6.12 A high-level qualitative view of how the option measures up against the criteria is summarised in **Table 11.**

Table 11: Counterfactual benefits

Can we meet FES predicted Entry levels?	Can we meet FES predicted Exit levels?	Does this option represent an appropriate level of resilience on the network?		Does this option allow National Grid to retain current capability?	Does this option allow the network to be operated in sensitivities beyond FES?
		Construction	Post Construction		

6.13 **Table 12** illustrates the availability of compression capability at Wormington. 'Parallel' represents the availability of capability above that delivered by Unit C, i.e. by running Units A and B in parallel. 'Single' represents the availability of at least one individual unit.

Table 12: Counterfactual availability

Capability	Current	2023	2030
Parallel	95.7%	95.7%	95.7%
Single	99.8%	99.8%	99.8%

[5] See section 7.2 for explanation of constraint costs.

6.14 The application of the 500-hours derogation does not lead to an immediate reduction in the availability of parallel operation in 2030 which remains at 95.7%. This does drop significantly from 2034 onwards as the duty increases. The availability of single unit capability also falls, although by a lesser degree.

<u>Risks</u>

6.15 The existing Avon units are over 40 years old. This brings an increased maintenance burden and higher probability of unavailability due to technical issues.

6.16 LNG supplies from the Milford Haven terminal are expected to increase in most scenarios as UKCS supplies decline. LNG supplies have not historically shown a strong correlation with the level of national demand, increasing the requirement for compression when LNG supplies increase at times of lower national demand. The 500-hours limitation would not be sufficient in most scenarios, leading to restrictions at Milford Haven terminal, and consequently very high constraint costs for industry and higher gas costs for consumers.

Option 1- Two New Gas Turbine (GT) Compressors (Two new units)

6.17 Build is assumed to be on adjacent unused land within National Grid boundaries and only requiring outages to connect the new units to the station pipework once they are built.

6.18 The cost breakdown of the option is given in **Table 13.**

Table 13: Two new units option cost

Option Title	Operating cost (£m)	Constraint cost (£m)	Total Installed cost (£m)	Asset Health cost (£m)	Decommissioning cost (£m)	Cost accuracy
1 - Two new units	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	P50

<u>Asset actions</u>

6.19 Construction of two new medium-sized gas-driven compressor units, built on adjacent unused land, within National Grid boundaries, commissioned by 2026. Avon Units A and B would be decommissioned once the new units are up and running. The two new gas turbine compressor units would be able to run in parallel with each other, and also with Unit C remotely which would enhance the resilience of the site. Currently units A and B cannot be remotely run in parallel with unit C

<u>Commercial actions</u>

6.20 There are no commercial contracts required to ensure compliance with National Grid obligations. Network constraints would be managed using existing tools.

<u>Benefits</u>

6.21 A high-level qualitative view of how the option measures up against the criteria is summarised in **Table 14**.

Table 14: Two new units benefits

Can we meet FES predicted Entry levels?	Can we meet FES predicted Exit levels?	Does this option represent an appropriate level of resilience on the network?		Does this option allow National Grid to retain current capability?	Does this option allow the network to be operated in sensitivities beyond FES?
		Construction	Post Construction		

6.22 **Table 15** illustrates the availability of compression capability at Wormington. ‘Parallel’ represents the availability of capability above that delivered by Unit C, i.e. by running

Units A and B in parallel. 'Single' represents the availability of at least one individual unit.

Table 15: Two new units availability

Capability	Current	2023	2030
Parallel	95.7%	95.7%	98.4%
Single	99.8%	99.8%	100.0%

6.23 Installation of new units leads to a slight increase in availability of parallel operation from 95.7 to % to 98.4%, this also avoids any restrictions from the 500-hours limit.

Risks

6.24 Unused assets if gas volumes are insufficient to need the two new compressors.

Option 2 – One New Large GT Compressor (One new large unit)

6.25 Build is assumed to be on adjacent unused land, within National Grid boundaries, and only requiring outages to connect the new unit to the station pipework once it is built.

6.26 The cost breakdown of the option is given in **Table 16.**

Table 16: One new large GT option cost

Option Title	Operating cost (£m)	Constraint cost (£m)	Total Installed cost (£m)	Asset Health cost (£m)	Decommissioning cost (£m)	Cost accuracy
2 - One new large unit	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	P50

Asset actions

6.27 Construction of one new large gas-driven compressor unit, to be built on adjacent unused land, within National Grid boundaries, commissioned by 2026. Avon Units A and B would be decommissioned once the new unit has been operationally proven.

Commercial actions

6.28 There are no commercial contracts required to ensure compliance with National Grid obligations. Network constraints would be managed using existing tools.

Benefits

6.29 A high-level qualitative view of how the option measures up against the criteria is summarised in **Table 17**.

Table 17: One large new unit benefits

Can we meet FES predicted Entry levels?	Can we meet FES predicted Exit levels?	Does this option represent an appropriate level of resilience on the network?		Does this option allow National Grid to retain current capability?	Does this option allow the network to be operated in sensitivities beyond FES?
		Construction	Post Construction		

6.31 **Table 18** illustrates the availability of compression capability at Wormington. 'Parallel' represents the availability of capability above that delivered by Unit C, i.e. by running A and B in parallel. 'Single' represents the availability of at least one individual unit.

Table 18: One large new unit availability

Capability	Current	2023	2030
Parallel (high flows)	95.7%	95.7%	79.3%
Single (low flows)	99.8%	99.8%	98.2%

6.31 Availability of 'parallel' capability (equivalent to that of the existing Units A and B) is now covered by the new larger unit (parallel operation no longer required), as this can no longer work with Unit C this reduces the availability to 79.3%.

Risks

6.32 One large unit has reduced flexibility compared to two smaller units and reduces the level of resilience. It has been assumed that the unit can provide resilience to Unit C at low flows but still shows a slight reduction in availability due to it now being one out of two as opposed to one from three.

6.33 This option also has no resilience at high flows with no back-up to the new large unit.

Option 3a – Emissions Abatement (Selective Catalytic Reduction (SCR)) on two units (SCR Two Units)

6.34 Emissions abatement would allow unlimited use of the Avon units post 2029.

6.35 The cost breakdown of the option is given in **Table 20.**

Table 19: SCR two units cost

Option Title	Operating cost (£m)	Constraint cost (£m)	Total Installed cost (£m)	Asset Health cost (£m)	Decommissioning cost (£m)	Cost accuracy
3a - SCR two units	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	P50

Asset actions

6.36 Emissions abatement on Avon Units A and B by 2029.

Commercial actions

6.37 There are no commercial contracts required to ensure compliance with National Grid obligations. Network constraints would be managed using existing tools.

Benefits

6.38 A high-level qualitative view of how the option measures up against the criteria is summarised in **Table 20**.

Table 20: Emissions abatement on two units benefits

Can we meet FES predicted Entry levels?	Can we meet FES predicted Exit levels?	Does this option represent an appropriate level of resilience on the network?		Does this option allow National Grid to retain current capability?	Does this option allow the network to be operated in sensitivities beyond FES?
		Construction	Post Construction		

6.39 **Table 21** illustrates the availability of compression capability at Wormington. 'Parallel' represents the availability of capability above that delivered by Unit C, i.e. by running A and B in parallel. 'Single' represents the availability of at least one individual unit.

Table 21: Emissions abatement on two units availability

Capability	Current	2023	2030
Parallel	95.7%	95.7%	95.7%
Single	99.8%	99.8%	99.8%

6.40 Once the abatement equipment is installed, availability is unaffected as the units are unchanged with no limitation on running hours. It was assumed that SCR will not impact the availability of the Avon units.

Risks

6.41 We estimate Units A and B will be unavailable for two years during installation of abatement equipment, which requires refurbishment of existing units, reducing site capability leading to significant disruption and large constraints costs. Installation requires both existing units to be completely refurbished. Emissions abatement technology increases the operational running costs of the compressor unit due to additional SCR related activities such as reagent usage, energy and replacement costs. Variation in summer flows from Milford Haven means the compressors may be needed during the summer; therefore, outages present a risk to compressor station operation.

6.42 Due to the age and asset characteristics of the non-compliant MCPD units, emissions abatement is unlikely to achieve the necessary NOx reduction and operational requirements. In addition, the investment associated with this option, is not cost effective when compared to installation of a new unit.

6.43 LNG supplies from the Milford Haven terminal are expected to increase in most scenarios as UKCS supplies decline. LNG supplies have not historically shown a strong correlation with the level of national demand, increasing the requirement for compression when LNG supplies increase at times of lower national demand.

Option 3b – Emissions Abatement (SCR) on one unit (SCR one unit)

6.44 Emissions abatement would allow unlimited use of one of the Avon units post 2029.

6.45 The cost breakdown of the option is given in **Table 22.**

Table 22: SCR one unit cost

Option Title	Operating cost (£m)	Constraint cost (£m)	Total Installed cost (£m)	Asset Health cost (£m)	Decommissioning cost (£m)	Cost accuracy
3b - SCR one unit	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	P50

Asset actions

6.46 Emissions abatement on Avon Unit A by 2029. Avon Unit B is maintained until 2029, following which it is placed on 500-hours derogation.

Commercial actions

6.47 There are no commercial contracts required to ensure compliance with National Grid obligations. Network constraints would be managed using existing tools.

Benefits

6.48 A high-level qualitative view of how the option measures up against the criteria is summarised in ***Table 23***.

Table 23: Emissions abatement on one unit benefits

Can we meet FES predicted Entry levels?	Can we meet FES predicted Exit levels?	Does this option represent an appropriate level of resilience on the network?		Does this option allow National Grid to retain current capability?	Does this option allow the network to be operated in sensitivities beyond FES?
		Construction	Post Construction		

6.49 **Table 24** illustrates the availability of compression capability at Wormington. 'Parallel' represents the availability of capability above that delivered by Unit C, i.e. by running A and B in parallel. 'Single' represents the availability of at least one individual unit.

Table 24: Emissions abatement on one new unit availability

Capability	Current	2023	2030
Parallel	95.7%	95.7%	95.7%
Single	99.8%	99.8%	99.8%

6.50 For most of the period availability is unaffected as the units are unchanged with no limitation on running hours to one Avon, however we expect this to fall by the mid-2040s as running hours increase and the 500-hours limit restricts the unabated Avon. Once the abatement equipment is installed, it is assumed that SCR will not impact the availability of the Avon units.

Risks

6.51 We estimate Unit A will be unavailable for two years during installation of abatement equipment, which requires refurbishment of the existing unit, reducing site capability. Installation requires the existing unit to be completely refurbished. Emissions abatement technology increases the operational running costs of the compressor unit due to additional SCR related activities such as reagent usage, energy and replacement costs. Variation in summer flows from Milford Haven means the compressors may be needed during the summer; therefore, outages present a risk to compressor station operation.

6.52 Due to the age and asset characteristics of the non-compliant MCPD units, emissions abatement is unlikely to achieve the necessary NOx reduction and operational requirements. In addition, the investment associated with this option, is not cost effective when compared to installation of a new unit.

6.53 LNG supplies from the Milford Haven terminal are expected to increase in most scenarios as UKCS supplies decline. LNG supplies have not historically shown a strong correlation with the level of national demand, increasing the requirement for compression when LNG supplies increase at times of lower national demand. The 500-hours limitation on the Avon without SCR would not provide sufficient resilience to the Avon with SCR and Unit C when parallel is required. This would lead to restrictions at Milford Haven terminal, and consequently high constraint costs for industry and potentially higher gas costs for consumers.

Option 4 – Decommission Units A and B post 2029

6.54 This option removes Avon compressor spend completely from 2029, saving expenditure on compressor assets for consumers (on an enduring basis).

6.55 The cost breakdown of the option is given in **Table 25.**

Table 25: Decommission post 2029 option cost

Option Title	Operating cost (£m)	Constraint cost (£m)	Total Installed cost (£m)	Asset Health cost (£m)	Decommissioning cost (£m)	Cost accuracy
4 - Decommission post 2029	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	P50

Asset actions

6.56 Maintain Avon Units A and B to allow operation up to 2029 and then decommission them.

Commercial actions

6.57 There are no commercial contracts required to ensure compliance with National Grid obligations. Network constraints would be managed using existing tools but the constraint costs would be significant.

Benefits

6.58 A high-level qualitative view of how the option measures up against the criteria is summarised in **Table 26**.

Table 26: Decommission benefits

Can we meet FES predicted Entry levels?	Can we meet FES predicted Exit levels?	Does this option represent an appropriate level of resilience on the network?		Does this option allow National Grid to retain current capability?	Does this option allow the network to be operated in sensitivities beyond FES?
		Construction	Post Construction		

6.59 **Table 27** illustrates the availability of compression capability at Wormington. 'Parallel' represents the availability of capability above that delivered by Unit C, i.e. by running A and B in parallel. 'Single' represents the availability of at least one individual unit.

Table 27: Decommission availability

Capability	Current	2023	2030
Parallel	95.7%	95.7%	0.0%
Single	99.8%	99.8%	91.3%

6.60 Availability of parallel operation reduces to zero when the existing Units A and B units are decommissioned. The availability of single unit operation is also reduced.

Risks

6.61 Network risk is increased significantly with this option. As previously shown in

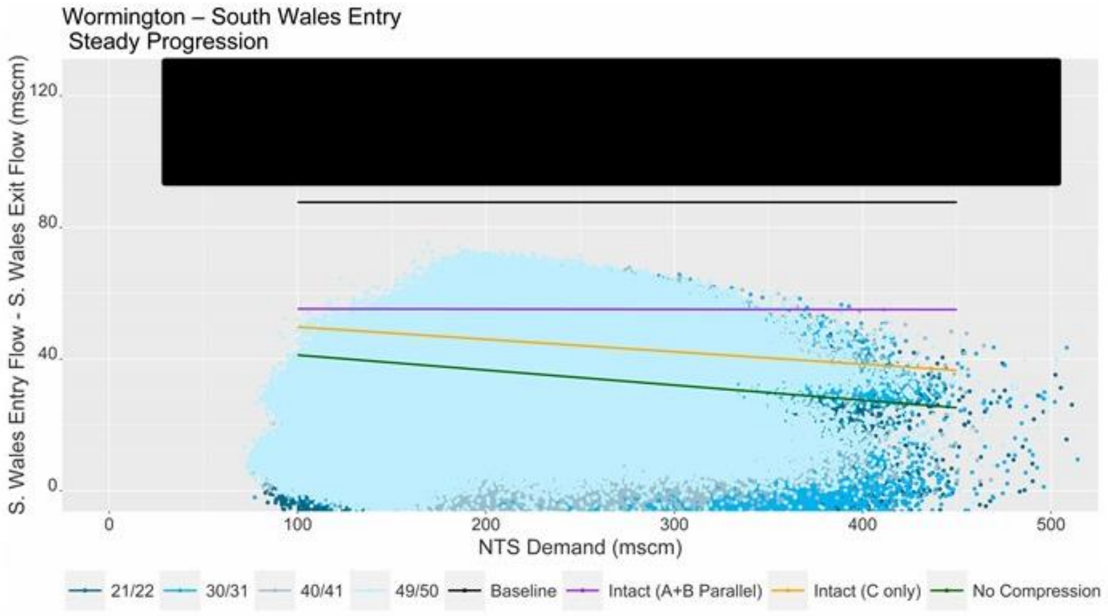

Figure 7, decommissioning Units A and B would significantly reduce the capability of the network to accept gas at the Milford Haven terminal.

6.62 LNG supplies from the Milford Haven terminal are expected to increase in most scenarios as UKCS supplies decline. LNG supplies have not historically shown a strong correlation with the level of national demand, increasing the requirement for compression when LNG supplies increase at times of lower national demand. Decommissioning both units would remove our capability to accept flows at the obligated level and remove resilience for Unit C, leading to restrictions at Milford Haven terminal, and consequently high constraint costs for industry and potentially higher gas costs for consumers.

6.63 Relying solely on the electric drive leads to the potential for significant outages if there is a failure due to the requirement to send the unit abroad for investigation and repair as well as a lack of spares.

Option Cost Estimate Details

6.64 The costs used in this analysis have been sourced and reviewed through eHub. The cost estimate for the preferred option (build two new units) is summarised in **Table 28**.

Table 28: Cost Estimate Details

MCPD 2 x 15MW (2 x GT units) on Greenfield				
Item	**Ofgem Guidance Note**	**National Grid Notes**	**Cost (£m)**	**% of Total Installed Cost**
Engineering Design	Detail costs for Studies/FEED/Detailed Design as appropriate.	Feasibility Studies and FEED works.	[redacted]	[redacted] %
		Detailed Design (by Main Works Contractor).	[redacted]	[redacted] %
Project Management	Element of Project Costs attributed to Project Management, not direct or indirect company costs.	Main Works Contractor Project Management.	[redacted]	[redacted] %
Materials	Bulk Materials, breakdown preferred.	Supplied by Main Works Contractor. (Included within 'Main Works Contractor' item cost).	-	0.00%

MCPD 2 x 15MW (2 x GT units) on Greenfield				
Item	**Ofgem Guidance Note**	**National Grid Notes**	**Cost (£m)**	**% of Total Installed Cost**
Main Works Contractor	Project Construction Contractor costs.	Main Works Contractor to carry out Detailed Design, Supply of Balance of Plant, Construction and Commissioning. Detailed Design cost shown in 'Engineering Design' item cost.	[redacted]	[redacted]%
Specialist Services	Costs for any additional services used to support the project i.e. surveys, data procurement etc.	Land and Easements.	[redacted]	[redacted]%
Vendor Package Costs	Costs of packages purchased for project.	Compressor Machinery Train Detailed Design and Supply by Compressor OEM. Costs are taken from those received during tender event (evaluation ongoing at time of writing).	[redacted]	[redacted]%
Direct Company Costs	Refer to Regulatory Instructions and Guidance for definition of direct company costs.	National Grid Project Management based on 52 weeks Detailed Design and 104 weeks Construction/Commissioning durations.	[redacted]	[redacted]%
Indirect Company Costs	Refer to Regulatory Instructions and Guidance for definition of indirect company costs.	National Grid indirect costs (Costs of Function %).	[redacted]	[redacted]%
Contingency	Contingency included in base cost estimate.	Technical and Commercial contingency associated with Compressor OEM tender (evaluation ongoing at time of writing).	[redacted]	[redacted]%
		Main Works Contractor contingency.	[redacted]	[redacted]%
Total Installed Cost	Forecast total project cost including contingency. Sum of all elements noted above.		[redacted]	**100.00%**
Cost Estimate Accuracy	This is an important element to give confidence that the engineering is mature and the costs can be relied upon.	P50 Please see cost accuracy table overview in 6.4 and CECS in annex A16.05 for overview of option costs.		

Options Summary

6.65 Error! Reference source not found.**Table *29*** summarises how the options compare against the criteria described in **Table 9.**

Table 29 Wormington Option Summary

Options	**Can we meet FES predicted Entry levels?**	**Can we meet FES predicted Exit levels?**	**Does this option represent an appropriate level of resilience on the network?**		**Does this option allow National Grid to retain current capability?**	**Does this option allow the network to be operated in sensitivities beyond FES?**
			Construction	**Post Construction**		
0- Counterfactual 500-hours Derogation						
1 - Two new units						
2 - One new large unit						
3a - SCR two units						
3b - SCR one unit						

Options	Can we meet FES predicted Entry levels?	Can we meet FES predicted Exit levels?	Does this option represent an appropriate level of resilience on the network?		Does this option allow National Grid to retain current capability?	Does this option allow the network to be operated in sensitivities beyond FES?
			Construction	Post Construction		
4 - Decommission post 2029						

Key Considerations

Resilience

6.66 Unit C is the lead unit on site up to its flow limit of 50 mscm/d. Units A and B provide resilience to Unit C up to this limit. For flows above 50 mscm/d Units A and B are the lead units. Unit C was not designed to operate in parallel with Units A and B, but with an engineer on site it can be used to provide resilience if either unit were not available.

6.67 As UKCS supplies continue to decline, LNG supplies into the UK are forecast to increase in most scenarios. Therefore, the requirement for compression at Wormington is forecast to increase over time, and consequently the importance of resilience capability at Wormington will also increase as illustrated in **Figure 3**.

6.68 The derogation of the existing units would not provide enough resilience as illustrated in **Figure 3**. This shows a sustained requirement for running hours above the derogated limit beyond 2030. Although emissions abatement would provide the required resilience, the works will require significant outages that are disruptive to consumers and expensive to manage; requiring the site to be operational throughout the year. The single large unit would not provide resilience for the low flow requirements of Unit C and Unit C could not provide resilience at high flows.

Current Capability and FES Entry and Exit levels

6.69 All options retain current capability apart from decommissioning Units A and B. As UKCS supplies continue to decline, LNG supplies into the UK are forecast to increase in most scenarios. Therefore, the requirement for compression at Wormington is forecast to increase over time and consequently, the importance of maintaining capability at existing levels at Wormington will also increase.

Flexibility and Sensitivities Beyond FES

6.70 Wormington compressor station offers a high degree of flexibility to the operation of the network in South Wales by providing capability to support high entry flows at Milford Haven LNG terminals, together with support to exit demands in South Wales when Milford Haven supplies are low, and support to demands in South-West England.

6.71 Two leading units are more flexible than one large unit. It is better to run a smaller unit at lower flows and at higher flows run two units run in parallel rather than turning down one large unit and running inefficiently and potentially outside the compliant range of operation. Smaller units can also better support lower entry and exit flows.

Milford Haven PARCA

6.73 The current VSD is limited to 50mscm/d and is not designed to be operated remotely in parallel with the Avon units. The design of the proposed new gas turbine units provides the ability for the VSD to be operated to run remotely in parallel with either of the new units.

6.74 With regards to the Milford Haven PARCA, the analysis does not currently identify any requirement for additional compressor units.

Option Summary Breakdown

6.72 To achieve MCPD compliance by 1 January 2030 and taking into account compressor investment at other MCPD sites, any new build or emissions abatement project at Wormington would need to begin Front End Engineering Design (FEED) in 2021. **Table 30** provides a comparison between all the options considered, the preferred option is highlighted in green.

Table 30: Comparison of Options (25 Year Costs)

Option Title	**Project start date (Establish Portfolio)**	**Project commissioning date**	**Project Design life**	**Operating cost (£m)**	**Total Constraint cost (£m)****	**Total CAPEX cost, including:**	• Total Installed cost (£m) *	• Asset Health cost (£m) *	• Decommissioning cost (£m) *	**Cost accuracy**
0 - Counterfactual 500-hours Derogation	2019	N/A	25yrs	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	P50
1 - Two new units	2019	2026	25yrs	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	P50
2 - One new large unit	2019	2026	25yrs	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	P50
3a - SCR two units	2019	2029	25yrs	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	P50
3b - SCR one unit	2019	2029	25yrs	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	P50
4 - Decommission post 2029	2019	2029	25yrs	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	P50

*costs to 2055, 25 years following implementation of MCPD in 2030

**see section 7.2, figure 13 for explanation of constraint costs. Figure 13 is showing annual constraints - the table shows total constraints.

Cost accuracy lifespan

6.75 For the recommended option (two new units), at this current ND500 4.1 stage, the cost is P50 estimate. Our cost proposal of [redacted] for two new units is based on the assumptions in Section 8.6.

Preliminary BAT

6.76 The Preliminary BAT assessment was built up through a series of staged sub-assessments of operational scenarios. This stepwise assessment process is underpinned by an environmental cost-benefit analysis methodology, which draws together environmental and operational priorities to support decision making. It has been used to assess different gas compressor unit combinations ('Preliminary BAT candidate options') that could potentially be used to deliver future process condition requirements at Wormington.

6.77 The assessment was undertaken independently from the CBA Tool analysis using a different methodological approach; it however incorporated common assumptions on cost, investment cases and future gas supply predictions (which would mean substantially increased gas flows at Wormington arising from higher volumes of imported LNG and / or high continental flows from 2030 to 2040 and beyond).

6.78 The Preliminary BAT assessment included consideration of constraint costs. The addition of constraint costs illustrates the future significance of Wormington to the NTS and led the assessment to indicate that the Preliminary BAT solution would be two new DLE units. Due to the substantial constraint costs associated with all options except the two new DLE investment case (option 1 – our proposed option). This conclusion is relatively insensitive to upward or downward variance in the modelled constraint cost.

6.79 The Preliminary BAT outputs tie in with the CBA outputs outlined and summarised in Section 7.

7. Business Case Outline and Discussion

7.1 This section shows the breakdown of operational costs for each option. These costs along with the others detailed in this section are included in the CBA to produce a NPV for each option.

Key Business Case Drivers Description

Constraints

7.2 The annual constraints costs are shown in **Figure *12***. These are highest in Option 4, where the MCPD units are decommissioned and not replaced. The counterfactual also results in significant constraints post 2030 as the Avons would be limited to 500 hours, this limit results in a reduced availability of parallel running.

[redacted]

Figure 12: Annual Constraints

7.3 The reduction in constraint costs delivered by option 1 – two new units is achieved by the delivery of increased availability of parallel operation. This is partly by ensuring the new units are configured to work alongside Unit C in parallel, and partly because of increased availability compared to the existing Avons.

Cost Breakdown

7.4 **Figure *13*** to **Figure *15*** show the breakdown of the costs included in the CBA. This is split into the investment costs for compressors, the constraints, and compressor running costs. This allows a comparison over the relative costs in each of the options.

[redacted]

Figure 13: Asset Costs included in the CBA

[redacted]

Figure 14: Constraints Costs included in the CBA

[redacted]

Figure 15: Operational Costs included in the CBA

Operating Costs

7.5 While there are differences in fuel costs across the options these are not of the same order as the constraints so are not a key factor in the overall decision. The option with the lowest fuel costs is, as expected, option 4 – Decommission MCPD unit 2029, as this only has costs for the remaining electric unit on site. The differential in the remaining options is driven by the different efficiency of the gas units on site.

7.6 The most significant driver for Wormington is the level of constraint costs. With Milford Haven flows expected to be significant throughout the period there is a high probability of constraints when the full capability of Wormington is not available. The reduction of these costs in option 1 more than outweighs the increased investment required to install the new units. The greater efficiency of the new units also results in fuel savings; however, this is not a key factor in the relative position of the options.

7.7 The sensitivity of the CBA output to variations in the level of constraints is assessed through the consideration of alternative supply and demand scenarios, as described below.

Business Case Summary

CBA Assessment

7.8 Based on our central scenario most of the options had a positive NPV compared to the counterfactual, as shown in **Table 31** and **Figure 16**.

7.9 The lead option is option 1, which has a positive NPV of £455m compared to the counterfactual. All the options where new units are installed, or abatement is used result in a positive NPV. The option where Units A and B are decommissioned results in a negative NPV.

Table 31: CBA Summary[6]

Short Name	NPV (£m)	Relative NPV (£m)
0 - Counterfactual	-£621 m	
1 - Two new units	-£166 m	£455 m
2 - One new large unit	-£477 m	£146 m
3a - SCR Units A and B	-£294 m	£328 m
3b - SCR Unit A + Unit B 500hrs	-£314 m	£307 m
4 - Decommission 2029	-£1766 m	-£1141 m

7.10 There will be a slight difference between the NPVs displayed in the justification papers and those in the Ofgem CBA template. The justification papers are based on our internal CBA model which uses Monte Carlo analysis to allow us to show the range of NPVs arising from the uncertainties in the cost, constraints and contracts. When the source data is entered into the Ofgem CBA template the predicted P50 of each element is used, this can be slightly different to the actual P50 of the simulation data. These differences only alter the overall NPV marginally and do not change the outcome of the CBA. The quoted NPV is based on 2065, 45 years after the start of the spend, the NPV at other time periods are available in the CBA submission.

[6] Note that these calculated NPVs assume a capitalisation rate of 73.5% as set out in CECS (Annex A16.05). This capitalisation rate has now been updated, and therefore there may be a minor mismatch between quoted NPVs between this document and the associated CBA (Annex A16.11). Please note that this does not affect the final proposed option. The impact of the updated capitalisation rate is reflected in the CBA document.

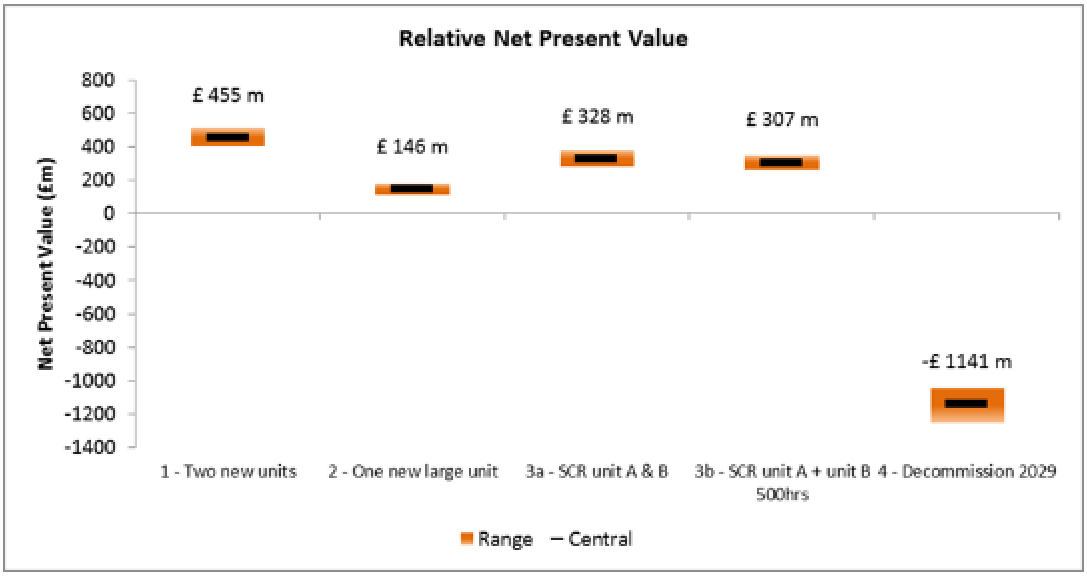

Figure 16: Relative NPV[7]

7.11 The CBA results show option 1 - two new units - provides the highest consumer value over the assessment period. This option results in a consumer saving of £455m when compared to the counterfactual option. The most significant driver for Wormington is the level of constraint costs. With Milford Haven flows expected to be significant throughout the period there is a high probability of constraints when the full capability of Wormington is not available. The installation of these two new units combats this constraint cost and delivers the most consumer value.

Sensitivities and Key Assumptions

7.12 To test the sensitivity of the Wormington case to different supply and demand scenarios we have tested the case against all four FES scenarios. Since the proposals are based on FES 2018 there is no specific scenario focussed on achieving the net zero target. However, the expected gas usage outlined in the net zero sensitivity in FES 2019 fell between the gas usage of the Two Degrees and Community Renewables scenarios which are examined here.

7.13 The Consumer Evolution scenario was used as a low case sensitivity. This scenario sees lower LNG imports resulting in low Milford Haven flows. This is driven by production of Shale Gas. The reduction of Milford Haven flows reduces the constraint risks linked to Wormington.

7.14 The Two Degrees scenario was used as a high case sensitivity. This scenario sees increases in LNG imports as annual demands remain relatively stable but UK domestic production declines. The increased LNG flows increase the constraint risk linked to Wormington. In addition, we have also tested Community Renewables to ensure all four FES scenarios are covered, this is between our Central case and Two Degrees.

7.15 The key assumptions behind the Wormington case are detailed in **Table *32*** below. We have applied sensitivities to the assumptions which could have an impact on the investment decision to test what would need to change for another decision to be favoured.

[7] See footnote 6

Table 32 Key Assumptions and Sensitivities

Category	Assumption	Base Assumption	Rationale	Sensitivities Considered	Sensitivity Outcome
CBA parameters	WACC	2.9%	Defined in RIIO-2	N/A	
	Social Time Preference Rate	3.5% (Years 0 – 30) / 3.0 % (30+)	Defined in Green Book	N/A	
	Regulated Asset Life	45 years	Defined in RIIO-2	N/A	
	Assessment Period	25 years	Based on lifetime of asset	N/A	
	Depreciation	Straight Line	Defined in RIIO-2	N/A	
	Capitalisation	73.5%	Defined in RIIO-2	N/A	
Supply/Demand	Supply/Demand Scenario	Steady Progression (2018 FES)	Central case for utilisation of Wormington	Two Degrees (High Case), Consumer Evolution (Low Case), Community Renewables	Preferred option unchanged in Two Degrees and Community Renewables; the Counterfactual has the highest NPV in Consumer Evolution
Investment Costs	Investment Costs	Option specific, see table 31 (P50)	Compiled by eHub and Compressor Team incorporating previous project experience	**Break Point**[8] +/- 30% (Monte Carlo)	+275% required to make 3a – Two SCRs favoured option / +300% required to make 3b – One SCR favoured option Other options not within range of Monte Carlo uncertainty
	Timing of Investment	FEED beginning April 2021 leading to Operational Acceptance in March 2027	Advanced delivery to facilitate outages for subsequent works at additional affected sites	N/A	
	Asset Health Costs	Option specific, see table 31 (P50)	Site-specific basis from historic data	+/- 30% (Monte Carlo)	Other options not within range of Monte Carlo uncertainty
Operating Costs	Site Operating Costs	Option specific, see table 31 (P50)	Site-specific basis from historic data	+/- 30% (Monte Carlo)	Other options not within range of Monte Carlo uncertainty
	Compressor Fuel Costs	Annual price 48 – 63p/th	BEIS reference scenario	N/A	
	Compressor Availability	Unit specific, see table 7 (LINK)	Based on observed running trips and expected return to service times	**Break Point**	+15% SCR units Not possible to make 3a-Two SCR units favourable +15% SCR units / +15% Avons / Remove 500-hour restriction would make 3b – One SCR unit favourable
	Constraint management volume	Specific to capability level	Output of network capability analysis	+/- 1 Standard Deviation (Monte Carlo)	Other options not within range of Monte Carlo uncertainty
	Constraint management pricing	As defined by Commercial Constraint Price Methodology	BEIS reference scenario	N/A	
	Constraint management method	50% buy-backs/50% locational actions	Reflective of tools available to manage constraints	25% buy-backs/75% locational actions	No change

[8] Break point is where we have tested how far the assumptions would need to move to change the investment decision.

Category	Assumption	Base Assumption	Rationale	Sensitivities Considered	Sensitivity Outcome
Emissions	CO2 volume	Unit specific emission factors	Based on observed performance	N/A	
	CO2 cost	Annual price 12.8 – 42.7 £/tonne	BEIS reference scenario	N/A	
	NOx volume	Unit specific emission factors	Based on observed performance	N/A	
	NOx price	£6,199 £/tonne	DEFRA damage costs	N/A	

7.16 The CBA was run under the high (Two Degrees) and low (Consumer Evolution) sensitivities, along with an additional sensitivity to ensure all four scenarios were covered. This is summarised in **Table 33**.

7.17 Across three of the four sensitivities Option 1 has the highest NPV by a considerable margin. Increasing LNG flows in three of the four scenarios result in significant constraints when parallel operation at Wormington is not available. In our low sensitivity, LNG imports are curtailed by significant UK shale production. In this low sensitivity the difference in the NPVs between the options is small suggesting Option 1 presents a low regret option even if this scenario were to materialise.

Table 33: CBA sensitivities – relative NPV[9]

Short Name	Description	Central Case Steady Progression	High Sensitivity Two Degrees	Low Sensitivity Consumer Evolution	Additional Sensitivity Consumer Renewables
Option 0	0 - Counterfactual	£ 0m	£ 0m	£ 0m	£ 0m
Option 1	1 - Two new units	£455 m	£ 1089m	-£ 42m	£ 188m
Option 2	2 - One new large unit	£146 m	£ 410m	-£ 45m	-£ 147m
Option 3a	3a - SCR Units A and B	£328 m	£ 910m	-£ 37m	-£ 115m
Option 3b	3b - SCR Unit A + Unit B 500hrs	£307 m	£ 828m	-£ 16m	-£ 83m
Option 4	4 - Decommission 2029	-£1141 m	-£ 2419m	-£ 61m	-£ 1543m

7.18 Increasing the lead SCR unit availability to 90% (2% above the new unit) and the backup to 100% (3% above the new unit) was not sufficient to make option 3a – Install two SCR favourable. This demonstrates that option 3a is not favourable even under very demanding assumptions – given the age of the units it is unlikely that their availability could be improved beyond that of new units. Moreover, the cost of improving the availability of the Avon units has not been calculated in the modelling.

7.19 If, in addition to increasing the availability of the SCR units we increased the availability of the unabated Avon to 100% and remove the 500-hours restriction through control system restricted performance it would have been possible to make option 3b – install one SCR the lead option. However, in the Preliminary BAT assessment, we assessed control system restricted performance as a means of meeting emissions compliance at Wormington. This was not found to be a BAT solution and has therefore been discounted due to the operational capability required at Wormington.

[9] See footnote 6

7.20 Altering the balance of constraint resolution so that 75% of constraints are resolved by locational actions and 25% are resolved by buy backs does not alter the preferred option in the CBA.

7.21 The cost of the new units in option 1 (install two new units) would have to increase by 275% to make Option 3a (install two SCR) favourable and by 300% to make option 3b (install one SCR) favourable. A cost increase of this magnitude is very unlikely.

Table 34 - Additional Sensitivities – Relative NPV[10]

Short Name	Description	Increase SCR availability	Increase SCR availability and remove 500-hours limit	75% Locational	275% cost increase
Option 0	0 - Counterfactual	£0m	£0m	£0m	£0m
Option 1	1 - Two new units	£454 m	£454 m	£252 m	£324 m
Option 2	2 - One new large unit	£146 m	£146 m	£78 m	£146 m
Option 3a	3a - SCR Units A and B	£427 m	£427 m	£190 m	£328 m
Option 3b	3b - SCR Unit A + Unit B 500hrs	£390 m	£455 m	£183 m	£308 m
Option 4	4 - Decommission 2029	-£1132 m	-£1132 m	-£651 m	-£1132 m

CBA Summary

7.22 The preferred option is option 1 (install two units), which has a consumer saving of £455m compared to the counterfactual in the central scenario. In three of the four scenarios option 1 comes out as the best option. In the low sensitivity, significant shale production limits the requirement to import LNG, reducing the constraint risk. However, in this sensitivity the difference between the relative NPVs is small compared to the other scenarios modelled – this indicates low regrets even if this more extreme scenario were to materialise. Given uncertainties over future shale production and the level of constraints in the other scenarios, we consider that proceeding with option 1 will deliver the best consumer value.

7.23 When testing against sensitivities of increased availability of compressors in other options the levels required to alter the decision were not credible. In addition, the level of cost increases required to alter the decision are significantly outside our level of cost uncertainty, and again are not credible. These give further weight to proceeding with the preferred option in the assessment, option 1 (install two units), as it demonstrates the best value for consumers across a wide range of sensitivities.

[10] See footnote 6

8. Preferred Option Scope and Project Plan

Preferred Option for this Request

8.1 Stakeholders have told us of the importance of sufficient network capability to ensure they are able to take gas on and off the system as and when they want and that we should ensure that we are taking steps to comply with air quality legislation. Ensuring sufficient capability at Wormington is key to achieving these stakeholder needs. The CBA assessment has shown that the options with investments in new compressors produced the best balance of benefits and risks to meet those needs across a range of scenarios.

8.2 The selected option, two new medium sized units, is based on the outcomes of our CBA, the Preliminary BAT assessment, and the flexibility needed to support Milford Haven terminal and South Wales flows. The new units have been sized for the network need. The option will be assessed as part of the full BAT assessment and tender process to ensure solution represents the best value for consumers.

8.3 The RIIO-2 business plan data table has been populated with two new medium units at Wormington, to give appropriate availability and support Milford Haven terminal and South Wales flows.

Commissioning dates

8.4 For the selected option the commissioning date is estimated to be 2026, aligned to our RIIO-2 and RIIO-3 outage plans. Decommissioning of the non-compliant units is expected to commence in 2027.

Project Spend Profile

8.5 **Table *35*** shows the high-level, indicative project spend profile. Entries in blue, in 2027 and 2028, are for the decommissioning of existing units once the new units are in operation.

Table 35: Project Spend Profile

Unit	Driver	Action	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Wormington A	MCPD	Replace						[redacted]	[redacted]			
Wormington A new		New	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]				
Wormington B	MCPD	Replace						[redacted]	[redacted]			
Wormington B new		New	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]				

Efficient Cost

8.6 Our costs are based on current assumptions made as a result of our experience of tendering for ongoing compressor replacement projects at Peterborough, Huntingdon, Hatton compressor sites and the St Fergus terminal (subject to reopener). This project will adopt our learning from ongoing compressor replacement projects covering items such as contracting strategy, surveys, bundling etc.

Project Plan

8.7 The milestones are based on our current view of investment in new compressors and the outcome of our CBA and the Preliminary BAT assessment. We've also considered wider works planned across the network. Internal stakeholder engagement has identified the best time to build the two new units, so our milestones are based on this timescale. **Table 36** is our project plan showing progression through the stage gate process, purchasing of long lead items, commissioning dates and key operational milestones.

Table 36: Wormington Project Plan

New Build			
Cycle	**Network Development Stage Gates**		**Indicative Dates Wormington**
Pre-FEED Stage 4.0 and 4.1	**T0**	Generation of Need Case	April 2019
	T1	Accept Need Case	April 2019
	F1	Initial Sanction	April 2019
	T2	Define Strategic Approach and Outputs Required to Deliver GT Handover to Delivery Unit	June 2021
FEED Stage 4.2	**F2**	FEED Sanction and Feasibility Sanction Includes BAT assessment and Compressor Machinery Train selection	June 2021
	T3	Agreement to Proceed to Conceptual Design	June 2022
	F3	Conceptual Design Sanction and Sanction of long lead items	June 2022
Tender Award Stage 4.3	**T4**	Scope Freeze	September 2023
Project Execution Stage 4.4	**F4**	Detailed Design AND Build Sanction (T4-F4-T5)	September 2023
	T5	DDS Challenge, Review and Sign off Maintenance Requirements Identified	June 2025
Acceptance Stage 4.5	**T6**	Post Commissioning Handover to GT; Operational and Maintenance Complete or Planned (Operational Acceptance)	June 2026
	F5	Project Closure	March 2027

Key Business Risks and Opportunities

8.8 Key risks include and currently identified mitigations are summarised in **Table *37***:

Table 37: Key risks and identified mitigations

No.	Risk	Mitigation (based on current view)
1	Outcomes from BAT and tender which may influence the choice and availability of technology – possibly including hydrogen;	Undertake Preliminary BAT to provide indication of possible available technology.
2	Site conditions, such as, onsite drainage and unknown buried assets, limiting options;	Engage with site to enable early above and below ground site investigations.
3	Delayed regulatory funding which could delay the projects and make tenders more expensive due to contractors having to commit to holding prices or limited numbers of contractors tendering;	Robust engagement with Ofgem.

No.	Risk	Mitigation (based on current view)
4	Changes in offshore operating models or new discoveries that increase UKCS supplies into Bacton resulting in lower LNG imports.	Early engagement with the Oil & Gas Authority (OGA) and environmental regulators.
5	There is a cyber security element to this project. Given the size of the cyber costs, there is a risk that external agencies may require additional levels of protection and security thus driving up costs.	Early engagement with external agencies and cyber technology providers on our preferred option and site requirements.
6	Wider changes affecting gas demand or supply such as an increase in shale gas or a move towards hydrogen not included in FES;	• Regular review and update of our FES analysis. • Proactive engagement with the wider energy industry to gain a view on trends to inform our technology choices.
7	Outages: • The overall potential volume of MCPD and other asset investment and maintenance works restricting outage availability which means Wormington work is scheduled for RIIO-2. Please refer to CECS for an overall timeline; • The unpredictability of customer flows, e.g. Milford Haven; • Appropriate flows for commissioning – largely dependent on Milford Haven.	• Ensure a robust deliverability plan for T2 investment is built and kept up to date on a regular basis. • Early engagement with shippers to gain understanding on current and future energy trends.
8	Land: • Building on the existing site could require lengthy outages due to working near to existing plant; • Local planning permission; • Environmental concerns during and post construction, such as noise, wildlife, water courses.	• Early engagement with local government; • Community projects.
9	Contracts: • Lead times for equipment purchase – we are a very small part of OEMs' market; • Availability of appropriate skilled resources. • High level of dependency on a single supplier (both OEM and Main Works Contractor (MWC)) – risk of being beholden to supplier.	• We will use our recent project experience at Peterborough and Huntingdon to inform our approach to internal and external resource and suppliers.

8.9 Key opportunities include:

- Bundling works with other MCPD impacted sites, bringing contracting efficiencies;
- Standardisation of our compressor fleet bringing benefits such as improved maintenance, improved operational efficiency, lower parts cost, lower inventory costs;
- Off-site compressor modular construction.

Outputs included in RIIO-1 Plans

8.9 Please refer to the CECS document for RIIO-1 outputs.